VARIABLE ANGLE LAUNCHER COMPLEX
California State Highway 39 at the Morris Resevoir
Morris Dam Test Facility
Angeles National Forest
Azuza Vicinity
Los Angeles County
California

HAER NO. CA-169

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PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
Western Region
Department of the Interior
San Francisco, California 94107

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HISTORIC AMERICAN ENGINEERING RECORD
VARIABLE ANGLE LAUNCHER COMPLEX
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Location: State Highway 39, four miles north of Azuza and twenty miles east of Pasadena, at the Morris Dam Reservoir, in the Angeles National Forest, County of Los Angeles, California.

USGS Azuza and Glendora Quadrangles, Universal Transverse Mercator Coordinates: Zone 11.

Date of Construction: 1943, Fixed-Angle Launcher (FAL); 1946-48, Variable-Angle Launcher (VAL)

Chief Engineer: F.C. Lindvall (California Institute of Technology), FAL; J.H. Jennison (Naval Ordinance Test Station), and F.C. Lindvall (California Institute of Technology), VAL.

General Contractor: General Tire and Rubber Co., Variable-Angle Launcher

Present Owner: U.S. Department of the Navy
Naval Command, Control and Ocean
Surveillance Center
RDT&E Division
Naval Research and Development
San Diego, CA 92152-5000

Present Use: Vacant, former naval testing facility to be demolished and the site returned to its natural state (estimated date 1997).

Significance: Morris Dam Test Facility (MDTF) was built at the Morris Dam Reservoir for the purpose of obtaining basic hydrodynamic data for use in design and development of Naval Ordinance, particularly air-to-water projectiles. The Variable-Angle Launcher (VAL) and its predecessor, the Fixed-Angle Launcher (FAL) were a consolidated effort between the scientific and military research and development communities. The VAL was the only structure in the nation where full scale, air launched projectiles could be tested at high velocities and variable entry angles into a body of water. MDTF served as a valuable resource during WWII and the Cold War era, spanning over 50 years. This is a unique complex where the setting has been unaltered by major modern development. The design is unique and all of its material is original. The components exhibit high quality, professional workmanship typical of contemporary naval military facilities. The facility has retained its overall feeling and appearance from the Cold War Era, maintaining a strong sense of time and place.

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DESCRIPTION:

The Morris Dam Test Facility (MDTF) is located at the Morris Dam Reservoir in Los Angeles County, California four miles north of Azuza and twenty miles east of Pasadena, adjacent to State Highway 39. Morris Dam Reservoir is in San Gabriel Canyon, part of the San Gabriel Mountains, in the Angeles National Forest. MDTF is situated on a steep peninsula jutting into the reservoir trom the west bank. This peninsula is approximately 130 teet long and 50 feet wide with steep rocky slopes. (See Figures #2). The maximum operating water level ot the reservoir is at 1,170 feet above sea level. The highest point of land on the peninsula is at 1,375 feet. Sixty feet above the highest point ot land at 1,435 teet, is the top deck of the overhead camera tower on the Variable-Angle Launcher (VAL), the highest point of the MDTF.

Numerous structures and buildings (approximately 30) are extant at the facility, which is currently closed. Most of the buildings have been vacated with all furnishings and documents removed. In general, the buildings are wood-frame construction on concrete slabs, with moderately sloped composition roofs. The noticeable exception is the VAL, built of cast-in-place concrete and welded steel. Four other smaller buildings, the three remote side view camera stations and the control station are also built of cast-in-place concrete.

The highest profile structure at the facility is the Variable-Angle Launcher. Transversing the peninsula, the VAL is oriented in the northeast-southwest direction. The Launcher and firing range face to the southwest opposing the counterweight ramp and car on the northeast side of the peninsula. The "A" trame structure measures approximately 260 teet in length (at the base) and 100 teet in height from its lowest point to the peak where it tapers to a length of 40 teet.

Five integrated components combine to form the VAL building. Three components are primarily cast-in-place concrete and the remaining two are welded steel. The two steel components are the overhead camera tower and the launcher bridge (including the bridge support carriage and the barges with the connecting bridge). The launcher ramp, counterweight ramp with car, and the five story, cellular "A" frame structure are the three concrete components of the VAL. (See Figure #8).

The launcher ramp varies from four feet to eight feet thick and is a heavily reinforced concrete slab poured directly on the rough surface of the natural rock foundation. Closely tollowing the steep slope of the peninsula, the ramp was built at a 45 degree angle. The slab supports and anchors the rails for the carriage of the launcher bridge. It measures 37 feet, 9 inches wide by 332 feet long. The slab cantilevers 5 feet, 1 inch on the northwest side and 10 feet on the southeast side. Twenty-eight inch wide cast-in-place stairs run the full length at each side of the slab. A track for the projectile car strattles the stairs on the east side of the slab and is capable of travelling the tull length, from top to bottom.

The counterweight slab was designed much lighter than the launcher slab. Measuring 19 feet, 10 inches wide by 352 feet long, the counterweight slab cantilevers 18 inches on the northwest side and 6 feet, 6 inches on the southeast side. It was constructed at an exact 30 degree angle.

Reinforced gunite, with a minimum thickness of 14 inches, was chosen for the counterweight slab because the construction bids indicated it would be less expensive than concrete. Similar to the launcher slab, cast-in-place stairs run the full length of the slab on the southeast side. Adjacent to the stairs, a personnel car runs on a track attached to the slab. The counterweight car, with a steel trame built on standard railroad wheels and axles, operates on standard gauge railroad tracks. The car body is made trom cast-in-place "heavy" concrete designed to include 3,200 pounds of scrap steel per cubic yard of concrete. The design weight of the counterweight car and pig iron ballast is 600 tons. Sixteen steel cables, of 2-1/8 inch diameter, connect the counterweight car to the bridge support carriage.

The main concrete structure of the VAL is a cellular continuation ot the slopes of the launcher ramp and counterweight ramp. The design is purely functional with clean and simple lines. Walls vary in thickness trom 12 inches to 24 inches. Since strength and rigidity were of primary importance, a minimum number ot doors and windows were provided. Various sized rooms are enclosed on six difterent levels. Rooms under the launching slab are approximately 20 feet wide. The rooms include: A secondary control room, an electronics lab, a smalf photo lab, generator rooms, a battery charging room and general storage areas. Rooms under the counterweight slab are approximately 10 teet wide. The rooms include: A large photo lab, a secured storage vault and general storage. Cantilevered walkways provide access to the upper deck levels. Stairs inside the structure provide access to some lower levels. However, some areas are only accessible trom the exterior ot the building at grade level.

With the overhead camera tower above, the architectural etfect is that of a ship's conning tower. Photograph #12 illustrates the modern architectural effect produced by the functional design of the concrete structure. The total weight of the concrete structure, is estimated to be 8.66 million pounds.

The main steel component ot the VAL is the all-welded, 300 toot long steel launcher bridge. The longest all-welded steel spanning structure built in the United States at that time. The typical section measures 22 teet wide by 35 teet high at the center line of the chords. (See Figure #14). The launcher bridge connects to the concrete launcher ramp via the bridge support carriage. This carriage rests on the two main rails attached to the concrete launcher ramp. The main rails were specially fabricated using two 1¾ inch plates with 1 inch webs spaced between. Each section weighs 4½ tons. The launcher bridge supports two 300 toot long launching tubes with 22½ inch and 32 inch inside diameters.

The VAL was designed to simulate air-to-sea weapon delivery and consequently this necessitates launcher tubes ot unusual power. The original construction included the instalfation of only the 22½ inch diameter launching tube and 500 cubic foot compression tank. However, the design was based on the tuture installation of additional launching tubes of various diameters. Figure #13 shows the proposed layout ot these tubes and related equipment. Additional sizes were not required after the successful use of a wooden sabot (pronounced sä bō). The sabot encased the projectile which allowed smaller torpedoes to be shot in a larger diameter tube.

Two tloating barges supported the muzzle end ot the launcher bridge. The steel barges were connected by two simple five-panel trusses tilted to bring the top chords together for support of the launcher bridge. The general arrangement, basic dimensions and relationships between the barges, connecting bridge and launcher bridge are indicated in Figure #15. A stairway, constructed so the treads are always level, provides access trom the upper carriage platform, through the launcher bridge, down to the connecting bridge and barges. The treads are automatically positioned by a linkage to the connecting bridge.

The overhead camera tower was built utilizing surplus army H-10 box girder sections. The tower rises 48 feet above the top of the concrete "A" frame structure. A platform provides working space for the handling of the cameras and related work. The camera box is driven along a cable by an electronic friction wheel to any point along the firing range centerline up to a distance of approximately 1800 teet trom the top of the launcher structure. An overhead system of three cables support the camera box. One end is fastened to the overhead camera tower on the VAL. The two supporting cables are anchored into the hillsides on the east and west side by means of a tive ton hand crank and a concrete-encased, steel beam deadman. Wire rope backstays link the tower to the counterweight slope for stability.

In addition to the VAL, a number of smaller concrete structures had a role in the operation and recordation of the launchings. The Control Station, built at the edge ot the work area approximately 60 teet east of the launching ramp, has an unobstructed view of the firing range. This small concrete bunker measures approximately 15 feet by 20 teet and is protected against possible tlying fragments by 2-1/8" thick convex bullet proot windows. In the Control Station, personnel monitor instrument panels tor all communications and recording systems as well as the sequencing of launch procedures.

Three general side view camera stations are situated high on the west bank of the reservoir with optimal views of the tiring range. Each typically measures 6 feet by 8 feet by 8 feet tall inside. The floor slab, walls and root are constructed of reintorced concrete. The camera ports and doors are metal sheathed wood designed to provide maximum protection against unauthorized entry or vandalism due to their close proximity to State Highway 39. Three 70 mm Mitchell motion picture cameras captured the tlight of the torpedo at 32 trames per second trom these fixed camera stations.

A side view camera car, below the general side view camera stations, is positioned along the 524 toot long railroad track parallel to the firing range on the west bank of the reservoir. This camera car would be located parallel to the estimated point of water entry. Customarily, a 35 mm Mitchell motion picture camera operating at 120 frames per second captured the last portion of the flight and the water entry. A second camera was also located in the side view camera car. This specially designed "Trajectory" or "Flare" camera had a 70 inch focal length lens with optically flat glass plates rotating at 30,000 revolutions per minute that could measure both velocity and trajectory angels. The railroad track is supported by a bridge structure utilizing surplus Army H-10 and H-20 box girder sections.

Immediately east of the VAL is the two story Administration Building. The original one-story structure was built in 1943. A second story was added during construction of the VAL in 1946-47. The rectangular floor plan measures approximately 24 feet wide by 44 feet long. The building housed offices, a drafting room, instrument and gyro rooms and a darkroom. The wood-frame structure with stucco exterior has a moderately pitched composition roof. The building served as the facility offices until the closing of MDTF in 1993.

Adjacent to the Administration Building is the Torpedo Shop. An irregularly shaped building of wood-frame and stucco construction, approximately 105 feet long, 62 feet wide and 16 feet tall. The Torpedo Shop was the main manufacture and repair facility for torpedoes and testing apparatus used at the MDTF for both the Fixed-Angle Launcher (FAL) and the VAL. The building included a machine shop, stockroom, tool room, welding shop and the main workshop.

The Fixed Angle Launcher, a 300 foot long metal tube anchored inside a concrete-lined trench, cuts across the peninsula on a northeast-southwest line with the launching range facing the opposite direction of the VAL. The 22½ inch diameter tube was set at a 19 degree angle and launched hundreds of full-scale torpedoes and test dummies. Currently, only the concrete channel remains. Completed in August 1943, the FAL was the first major testing apparatus constructed on the peninsula. FAL tests helped dramatically improve the performance of the U.S. Navy's air-drop torpedoes during World War II.

The FAL continued to be in operational condition until the mid-1950's. Having been displaced by the larger and more flexible VAL, the FAL lost its significance to the MDTF operations and was dismantled by 1960. Compression tanks used for the firing of the FAL are still extant and located immediately above the concrete trench of the FAL.

The FAL Control Station was built on a concrete slab notched into the north side of the peninsula approximately 20 feet west of the bridge over the FAL trench. This small wood-frame building, 7 feet long, 5 feet wide, and 8 feet tall, overlooks the former FAL firing range. This Control Station was the operational monitoring station for the Fixed Angle Launcher. Many of the control gauges, electrical switches and fuses are still in place despite the earlier dismantling of the FAL.

At the lower east end of the peninsula are numerous support structures. Many are miscellaneous storage sheds of single story wood-frame construction. A Public Works Garage and Weld Shop building was located at the far east end of the peninsula. This single story wood-frame building was probably constructed in 1953. It measures 44 feet long, 21 feet wide, and 13 feet high. The large room was a garage for vehicles. The small room was the weld shop.

Also at the east end of the peninsula is the Carpenter and Electric Shop building. Constructed in 1944, it was originally the Carpenter and Paint Shop. The wood shop was equipped with table, jig, and circular saws, portable drills, concrete drills, drill press, sanders, grinders and air compressors. A smaller room housed the paint shop. In later years, a new paint shop was built and the smaller room converted to the Electric Shop.

Additionally, a number of single-story structures were built at the northeast end ot the peninsula in the 1950's-60's. Eight test cells are housed in three separate concrete structures. Test cells were used to test the torpedo engines and propulsion systems under different conditions. Many experimental ideas and designs would be tested prior to a launch using the VAL.

The dive shop is a small metal quonset hut located at the southeast end of the peninsula adjacent to the boat ramp. It was used for storage of equipment and materials needed for the recovery of sunken projectiles. The original wood-lrame dive shop was destroyed years ago when the decompression chamber exploded.

Beyond the dive shop, to the west, is the polymer test lacility. This unusual lacility was designed to study the drag and noise reduction obtained by using polymer solutions. The facility includes a slurry manulacturing room as well as a mobile mixing unit with a 5,000 gallon capacity. Ditlerent piping is used to investigate changes in noise levels, including tully instrumented acoustically damped piping.

At the far eastern tip of the peninsula is the boat launching ramp which extends into the reservoir. It was constructed in 1944 as part of the FAL torpedo recovery system. By 1949, a large wooden floating pier had been attached to the ramp tor the mooring of boats and testing barges. The pier was removed in 1993 during the closing of the MDTF. A 15 foot wide by 197 foot long concrete ramp is all that currently remains.

A large number of underwater testing devices were also used at MDTF. An underwater cableway range could test torpedoes tethered to a cable over a 2,500 foot distance. Sonic barges were used to study and measure various underwater acoustic phenomena. A forty toot long rail launcher could be lowered underwater from a barge for launching 10 inches to 22½ inch projectiles at depths up to eight feet. And lor deeper tests, a barge was able to be lowered 150 feet underwater for static tests, acoustic tests or launchings.

Also water related was the hydrostat facility. Two tanks conducted static tests and pressure measurements of hydrodynamic bodies. Both tanks were water activated up to 10,000 pounds per square inch. Minor modifications to either tank would allow operating pressures of up to 15,000 pounds per square inch.

The sinking rate of an object also was measured and tested. A special barge mounted device was used for measuring underwater sinking rates. Magnetic pickups on a freely moving cable drum would yield velocity data used in computing sinking rates.

A large "slingshot" facility was located near the dam (See Figure #3). By use ol an overhead cable and bungee shock cords, a variable angle, high velocity launcher was made. Various arrangements were available to create water entry ol up to 200 feet per second and entry angles lrom 60 to 90 degrees. A free fall drop was also possible.

North of the VAL peninsula, on the abandoned FAL range, a helicopter air drop range was built. Air drops were always made in a southerly direction due to natural terrain limitations. Camera coverage of the air drop range was made from the west shore and the VAL peninsula. Immediately north of the air drop range, at Islip Canyon, was the heliport for the entire facility.

Overall, the buildings extant at the Morris Dam Test Facility are in good condition. Most are in their original form with only minor changes over the 50 year span of the complex. The site has retained the feeling of a Naval facility during the Cold War era, partly due to its setting in the Angles National Forest where no major modern development has occurred since the construction of this facility. The MDTF has always been a secured site. Access to the facility is guarded 24 hours a day at the main gate by Highway 39.

HISTORY:

Morris Dam Test Facility (MDTF) is located at the Morris Dam Reservoir, in the San Gabriel Mountains, in the Angeles National Forest, in Los Angeles County just four miles north of Azuza and twenty miles east of Pasadena. The first substantial activity in the area was generated by the discovery ot gold on the east tork of the San Gabriel River in 1855. The Angeles National Forest was created in 1892, originally named the San Gabriel Timberland Reserve. It was the tirst area set aside in California atter the passage ot the Forest Reserve Act of 1881. The primary goal of the Forest Reserve Act was the conservation ot watershed.

During the 1920's and 1930's, several initiatives were undertaken to control the flow of the San Gabriel River and conserve its water resources. The City of Pasadena built Pine Canyon Dam (later renamed Morris Dam after Engineer Samual B. Morris) during this era to provide water retention for domestic use. Construction began in 1932 and was completed in 1934. The 245 foot high, 756 foot wide concrete dam holds 42,000 acre teet of water in the four mile long reservoir. (Van Wormer 1985:23-30). MDTF was established seven years, later in 1941.

The history ot MDTF is linked to the research and development ettorts in the field of underwater ordinance. Between World War I and World War II, there was little research or development in this field. Therefore, in the early phases of World War II, only outmoded weapons were available. Aircraft pertormance with respect to speed, load carrying capacity, range and maneuverability had advanced well ahead of the performance of aerial torpedoes. Torpedo release altitudes and air speeds were so low that the aircratt were literally "sitting ducks" during their approach runs. Plane and pilot losses were very high, and successtul torpedo bomber plane operations were correspondingly low.

The outbreak of World War II was a catalyst for the mobilization ot the scientitic community in the United States. During early 1940, key members of the National Academy of Science realized the need to mobilize the nation's scientific community. When France fell to Nazi Germany in June 1940, Academy member Dr. Vannevar Bush, a physicist and president ot the Carnegie Foundation, approached President Franklin D. Roosevelt with a plan to form a coalition of scientists, similar to the National Research Council tormed during World War I. Roosevelt agreed and established the National Defense Research Committee (NDRC) with Dr. Bush as chairman. (NOSC 1991:5; HOVDE 1946:V). The role of NDRC was to guide basic research and aid the military in the development ot weapons and systems.

During the later part of 1940, the NDRC contacted both civilian and military laboratories and institutions to locate available facilities for potential research programs. Additionally, the NDRC formed several research committees to investigate the immediate and potential needs for military research. The reports of these committees outlined many areas where the current military weapons and systems were lagging behind. A major area of concern was anti-submarine warfare.

Since 1939, the beginning of World War II, undetected German U-Boats had achieved great success in the sinking of merchant and passenger ships. The U.S. Navy was concerned about their own potential capabilities to defend against such attacks. In January 1941, the NDRC

Subcommittee on Submarine detection filed a report stating that U.S. Navy submarine systems and detection methods had not advanced since the end of World War I. Expanded research and training would be needed. Under U.S. Navy direction, NDRC moved to establish two laboratories, one at East London, Connecticut, and the other at Point Loma in San Diego, California. In April 1941, the University of California through negotiations with the NDRC established the University of California Division of War Research to operate the San Diego Laboratory.

By December 1940, Dr. Bush had realized that the advisory and research capabilities of the NDRC were not sufficient to administer the rapid interchange and development of scientific knowledge to the military. Bush proposed that another organization administer the scientific research related to the national defense. In June 1941 President Roosevelt agreed, and through executive order formed the Office of Scientific Research and Development (OSRD). The OSRD incorporated the NDRC into its organization and became the management agency for the many Research and Development contracts that would be administered during the duration of the war. These OSRD projects would encompass varied subjects ranging from health issues to atomic ordinance (NOSC 1991:7).

In the summer of 1941, the California Institute of Technology (Cal Tech) was becoming known as a center of wartime military research. Cal Tech faculty established their own "Council of Defense Cooperation" in May of 1941. Later that year, Cal Tech offered their facilities and staff to the NDRC. Three factors at Cal Tech interested the NDRC and the military. The first was Dr. Charles Lauritson and his program in rockets and rocket weapons. Second was the Guggenheim Aeronautical Laboratory's jet propulsion project. And the third was Dr. Max Mason (Christman 1971:116). Dr. Mason had been a leader in anti-submarine research during World War I.

Before the outbreak of World War II, Dr. Mason had worked on a limited, but workable, echo-ranging system (now known as sonar). However, even with sonar, the U.S. Navy's ordinance for attacking submarines was primitive. The Navy still used the "ash can" depth charge. This large and heavy explosive could only be shot a short distance away from large ships or dropped down directly from crafts too small to mount the large launchers. Also, the bulky ordinance sank slowly and unpredictably through the water. These negatives, along with new submarines that could submerge faster and much deeper than before, required the need to develop new anti-submarine ordinance. Plans for a lighter "thrown-ahead" depth charge ordinance, such as the British "Hedgehog" launcher with rocket propulsion for greater speed and trajectories, were soon in the works (Christman 1971:116).

In August 1941, OSRD adopted a project to deal with the U.S. Navy's need for new anti-submarine weapons. The NDRC chose Dr. Mason and Cal Tech to head and operate the project. Under contract OEMsr-329, OSRD gave Cal Tech the task of researching and testing anti-submarine weapons and underwater ballistics.

The contract dictated that Cal Tech construct adequate testing facilities for underwater ordinance as well as mathematical and scale model studies of fundamental ballistics for water entry and underwater travel. Cal Tech chose the Morris Dam Reservoir as their testing facilities site.

By the end ot 1941, Cal Tech's tacility at the Morris Dam Reservoir was in full operation. Along the top and face of the dam and in the reservoir, Cal Tech personnel built testing ranges, laboratories and support tacilities. Cal Tech scientists did their early tests in cooperation with the Navy laboratory at New London, Connecticut. Their focus was on testing and design ot depth charges and fast sinking bombs. Cal Tech's early work at Morris Dam helped develop the "mousetrap" anti-submarine launcher that provided smaller vessels a powerful anti-submarine weapon. The mousetrap became a key weapon in U.S. anti-submarine wartare as early as mid-1942. During the war, Cal Tech researchers tested over 50 different U.S. and British weapons and systems at Morris Dam (NOSC 1991:14; MASON 19469:3-5).

In 1943, the U.S. Navy turned to the scientists at Cal Tech with another major ordinance problem, the extremely low release altitudes and velocities of their standard air-dropped torpedo, the Mk 13. This torpedo required aviators to maintain their aircraft just 50 feet above the water's surface at a speed of only 100 knots to allow the torpedo to survive the drop and possibly continue on a straight course. The low flight level and slow speed made the aircratt and their pilots easy targets for anti-aircraft guns. The U.S. Navy's dissatistaction with the standard Mk 13 torpedo's limitations was confirmed in the Battle of Midway, June, 1942. The Japanese Navy shot down 40 ot 43 U.S. torpedo planes while the U.S. planes registered no known torpedo hits on enemy ships (Christman 1971:166).

During late 1942 and into 1943, the U.S. Navy's Bureau ot Ordinance (BuOrd) contracted the NDRC to research improving the Mk 13 and the development of the new Mk 25 torpedo. The U.S. Navy needed a testing facility to study the etfects of speed and entry angles on torpedo performance. BuOrd's immediate objective was the modification of the Mk 13 torpedo to increase its current pertormance. Their long-range objective was the development ot completely new designs that would permit greater water-entry velocities and flatter entry angles. Due to the earlier successes of the Cal Tech scientists and the standing OSRD contract, the NDRC assigned Cal Tech to the fundamental study of the full-scale hydrodynamic phenomena associate with high-speed water entry and the underwater travel of torpedoes.

Cal Tech engineers selected a site for the new full-scale test launch facility approximately 3,000 feet upstream from Morris Dam on a steep peninsula jutting into the reservoir. This site met the necessary requirements of a 5,500 foot straight course with an average water depth of 100-140 feet (Lindvall 1946a:13-15; Lindvall 1946b:21). Cal Tech named engineer F.C. Lindvall as supervisor of the Torpedo Launching project and construction began in 1943.

To implement the tull-scale test shots of torpedoes, a 300 toot long Fixed Angle Launcher (FAL) was constructed on the northeast slope of the steep peninsula. A 22½ inch diameter tube, set at a 19 degree angle, launched tull-scale torpedoes by means of compressed air. During the rest of 1943 and into 1944, Cal Tech made hundreds of test shots with Navy provided Mk 13 torpedoes and Cal Tech designed dummy torpedoes. The test results proved that a new "shroud-ring" welded onto the tail fins ot the torpedoes would increase control and strength ot the torpedo. Cal Tech researchers made other improvements and modified the Mk 13 torpedo enabling safe and etfeotive drops trom altitudes of 800 feet and speeds ot 300 knots. By the summer ot 1944, the moditied Mk 13 torpedoes were being delivered to the pacitic fleet. At the Battle of the Leyte Gulf in October 1944, U.S. forces sank 60 Japanese ships. The U.S. Navy credited the improved Mk 13 torpedo with helping the aviators achieve this victory. (Lindvall 1946a:13-15; Lindvall 1946b:21; NOSC 1991:15-16).

The success of the improved U.S. Navy Mk 13 torpedo was linked to the unique facilities at the Morris Dam test range. The facilities on the peninsula included several buildings used to support the operations at the FAL site. Near the top of the peninsula was an office building with gyro and instrument shops, administration offices and a darkroom. Adjacent to the FAL was the torpedo shop. Operated by a 12-man crew, the torpedo shop repaired, constructed and prepared torpedoes and equipment for launchings. A concrete bridge was built over the FAL to access the lower end of the peninsula. The boat facilities, carpenter shop and miscellaneous storage was located on the lower end of the peninsula.

The FAL originally used a 1,150 cubic foot, 150 pound per square inch pressure tank, connected to the firing tube through a "Y" joint, to launch the torpedoes. Cal Tech engineers later added rocket boosters at various points along the tube until a larger pressure tank could be installed. Still and motion picture cameras were placed along the test range that included a camera car on a railroad track parallel to the launcher at the edge of the reservoir. A sound range was also placed in the reservoir which included eight hydrophones and six sonarbuoys connected to a sound recording house along the west bank of the range. (Lindvall 1946b: 21-23).

After test firings, a boat crew would recover the torpedo, usually floating, and drag them back to the recovery ramp where they would be loaded onto a trailer and driven back to the upper facilities. A dive crew was also available to recover sunken or damaged torpedoes. During the studies connected with the FAL, it became apparent that one of the most important variables in water entry and subsequent underwater trajectory was the angle of entry.

The success and value of the wartime research had become apparent to the U.S. Navy. The value of a permanent testing facility of the caliber of the Cal Tech operation was realized as early as 1943. At about this time, Cal Tech's Dr. Lauritson and Navy Commander Sherman E. Burroughs of the BuOrd began to work together to find more range space for the expanding rocket program. They helped convince the U.S. Navy to establish a permanent testing facility at the site of the new rocket program testing range at Inyokern, California, 155 miles northeast of Los Angeles. In December 1943, BuOrd established this range as the new Naval Ordnance Test Station (NOTS). During 1944, $11 million was obligated toward construction of the permanent facilities of the base. (Christman 1971:162-193; NOSC 1991:16-17)

As the Allied Forces moved toward victory in mid-1945, the value of wartime research operations had made their mark on plans for the peacetime Navy. In July 1945, the U.S. Navy agreed to transfer the wartime rocket and torpedo programs directly to the command of NOTS-Inyokern. The U.S. Navy then transferred all of Cal Tech's OSRD contracts to a new contract between the BuOrd and General Tire and Rubber Company (GT&R). Cal Tech's administrators began to feel that they did not want to take on the responsibility of having their staff oversee the large contracts planned tor the post-war period. In July 1945, Navy Commander William Keighley took command of the Morris Dam operations from F.C. Lindvall. On September 1, 1945, the U.S. Navy tormally transterred the Morris Dam Facility and activities to NOTS. (Gerrard-Gough 1978:186-188, 230).

During this transition period, Naval Commander Keighley intertaced directly with the BuOrd in the transitioning ot the facility operations. As the Cal Tech engineers prepared their final reports, the BuOrd placed a high priority on the Morris Dam Facility and began planning for what would be termed Phase II ot the U.S. Navy's Underwater Torpedo Program. The U.S. Navy oftered many of the Cal Tech employees the opportunity to continue their work in civil service for the U.S. Navy. By 1948, over 700 former Cal Tech employees would be working at the Pasadena and Morris Dam facilities (NOSC 1991:30). Some early transitional problems did occur. However, once NOTS' Commander named former Cal Tech engineer William Henry Saylor as Technical Coordinator and Head of the Underwater Ordnance Section, the command troubles improved and stabilized. The inclusion of the Pasadena and Morris Dam facilities helped make NOTS the top naval research and development laboratory on the west coast. (Gerrard-Gough 1978: 230-231, 298-299).

The Bureau of Ordnance's interest in expanding the Morris Dam facility was immediately apparent. In July 1946, BuOrd established the goals tor Phase II of the torpedo program. This included new lightweight torpedoes designed to operate on the newly developed jet aircratt. This meant that a 1,000 pound torpedo (the Mk 13 weighed 1,500 pounds) would be required to handle speeds of 600 knots and drops trom altitudes of 10,000 feet. NOTS engineers realized that a new facility would be needed at Morris Dam tor research and development of such ordinances. (Gerrard-Gough 1978: 299; NOCS 1991:31).

Cal Tech engineers had already considered the possibilities of these new challenges. In tact, Cal Tech had considered a variable-angle launcher even before they built the FAL in 1943. This concept was shelved in 1943 due to time and cost restraints. The tinal report by Cal Tech scientists and engineers in November of 1945 included a chapter of a planned variable-angle launcher. The Cal Tech engineering team's concept called for the modification of the FAL tor added tlexibility in the testing program. Cal Tech engineers, under the direction of F.C. Lindvall, discussed the benetit of the variable-angle launcher due to entry angle being the most important variable in testing torpedoes. The design ot a variable-angle launching tacility was continued by the Underwater Ordinance Section of NOTS-Inyokern.

Three general schemes were evaluated for numerous operational characteristics including: velocity, launching angle, counterweight required, retaining walls required, excavation required, and total estimated cost. The three potential schemes were: tower-system launcher, a dual-rail launcher, and a barge-type launcher (See Figures #4, #5 and #6). All three used dittering methods to move a large steel truss that would house the launching tubes. Lower tirst cost, suitability for construction at the selected site and maximum operational tlexibility dictated selection of the third scheme, the barge-type launcher. The preliminary estimated cost was $511,300.

The U.S. Navy delayed construction of the VAL immediately after World War II due to budget considerations. Still, BuOrd realized the potential value and continued to promote the construction. The Bureau ot Ordinance, U.S. Navy, directed the General Tire and Rubber

Company of California to construct a Variable-Angle Launcher by letter dated January 25, 1946, (SMITH 1952:1). Assigned as project engineer for the VAL were James H. Jennison (NOTS) and F.C. Lindvall (Cal Tech). Construction began in April 1946.

Although the site, located next to the FAL on the peninsula at Morris Dam Reservoir, had the best slope and range parameters, geologic surveys showed the peninsula was fractured and had the possibility of a surface rock slip or of a slip along a deep circular arc in the peninsula. The NOTS engineers began a project to remedy the situation by literally "cementing" together the fissures in the peninsula. James Jennison later recalled that contractors placed over 40,000 sacks of cement into the mountain through diamond-bit drilled holes up to 150 feet deep in order to stabilize the base for the VAL's construction (Gerrard-Gough 1978: 301-302). Such costly construction problems and solutions brought the total cost estimate for the VAL to nearly two million dollars. The VAL's unique design was another factor in its high cost. The NOTS engineers were forced to try to cut costs and scramble for materials in the post war period.

The most costly and significant feature of the VAL was the 300 toot long, all-welded, steel launching truss that housed the 22½" diameter, 300 foot long launching tube. (Figure #14). Fortunately, the Columbia Steel Company donated the large amount of steel needed for the launching truss. The relative merits of welded versus riveted construction were examined to determine the best method of construction for the structure. Preliminary studies indicated that a riveted structure would weigh 60% more than a welded structure while the cost would be approximately the same. Rigidity was a primary prerequisite needed to reduce the deadload deflections at various angles. The continuity inherent in welded construction and implied redundancy were contributing factors to choosing an all-welded truss. At its completion in 1948, the VAL Launcher truss was the longest all-welded span ever constructed in the United States.

The launching truss is raised and lowered on a track with the aid of a counterweight. A concrete "A" frame structure saddling the peninsula, with the launcher ramp on the southwest side and the counterweight ramp on the northeast side, provides the structural support. The main concrete structure is a cellular continuation of the slopes of the launcher ramp and counterweight ramps. The design is purely functional and houses electrical machinery and recording equipment. This structure also supports the main drive machinery and the camera cable tower. The counterweight was designed to suit the special requirements ot the launcher. Standard railroad track and wheels provide support for the concrete body of the counterweight car. Sixteen 2⅛" diameter cables link the counterweight car to the launcher bridge. Jennison moved to save more money by having the counterweight car built of concrete instead of pig iron. After 30 months, with all the cost cutting, added construction efforts, and material shortages, the VAL was completed at a cost of nearly two million dollars. (Gerrard-gough 1978: 301-302; NOTS 236 1950:7-U).

On May 7, 1948, the U.S. Navy held the official dedication and firing ceremony for the VAL. This coincided with the official opening of NOTS-Inyokern's new and elaborate Michelson Laboratory. Many dignitaries who had come from Washington D.C. and throughout the United States for the May 8th NOTS ceremony, attended the VAL opening at Morris Dam. Admiral Switzer, the commander ot NOTS, headed the ceremony and dedication. Dr. W.V. Houston, the president of Rice Institute, Texas and a Cal Tech alumnus, made the dedication speech. Dr. Houston spoke on the important role ot research fo the National Detense and concluded that "to this end, I am sure thaf this new Morris Dam insfallafion will make a magnificenf confribution". (Gerrard-Gough 1978:354).

Af the dedication date, although not complete, the VAL was sufficiently advanced to permit restricted use ot the launcher. Construction, with the exception ot some instrumentation, was completed in September 1948. The operation of the VAL was similar to that of its predecessor, the FAL. As wifh the FAL, the test torpedoes and dummy torpedoes would be assembled and fitted wifh testing instruments in the Torpedo Shop. Any torpedo that was less than the 22.5 inch diameter of the fube would be fitted wifh a wooden "sabot" that allowed it to tlow smoothly fhrough the tube. The torpedoes were placed on carfs in the Torpedo Shop and rolled over to the loading plattorm adjacent to the tive story concrete structure of the VAL. The cart was rolled onto the projectile car and raised or lowered to the level of fhe projectile loading deck. A small derrick crane would pick fhe torpedo up oft the cart and posifion if for loading into fhe breach ot the tube. The propulsion was provided by a 550 cubic foot capacity impulse tank rated at 1,000 pounds per square inch, permitting larger volumes and higher pressures for projectile accelerafions.

Engineers and technicians in the VAL control station, just to the east of the VAL, would coordinafe the operations of the VAL launch procedures. Cameras along the west shore of the reservoir and on the VAL itself were sequenced to photograph the torpedo as it lett the launching tube after firing. The engineers and technicians would also coordinate the operations of the sonarbuoys and other recording devices ot the Sound Range located in the water direcfly in tronf of the VAL.

When all reporting stations were ready, fhe VAL control stafion began the launch sequence. At firing, the camera and sound recording systems were triggered electronically to record fhe test. As with the FAL, the floafing torpedoes were recovered by boat and the sunken ones with diving feams (NOTS 236 1950). Through the years the VAL operating procedures would change very liftle.

During the tive years following fhe VAL's construction, from 1948–1953, Morris Dam Test Facilify experienced its peak ot activity and growfh. Over the first fhree and halt years of operation the VAL would launch 1,207 fest firings (VAL Launching Records 1950–1951). The Navy's scientists operated the VAL's sound range and sfill, underwafer and motion picture camera facilifies with state-of-the-art equipmenf. During this early NOTS period, the Navy also constructed several new ancillary facilities on the dam near the old Cal Tech ballisfics facilifies. This area became known as the Small Caliber Range (SCR) and included: 150 foof high tower wifh platforms for rocket launchers, an above water missile launcher (slingshot), a barge mounted rail launcher and small barge-mounted VALs. Also, Navy scientists expanded the small propulsion laborafory at Morris Dam tor experiments with chemical fuels, high-energy batteries and various thrusf producing mechanisms (NOSC 1991:32; NOTS 236 1950:50). From September 1948 to June 1953, the Navy would construcf 17 new structures on the peninsula for testing and support of the Morris Dam Test Facility (BuOrd Sketch 209887; 475328).

During the 1950's, Morris Dam and NOTS continued to play an important role in Naval Research and Development (R&D). The rise of the military's peacetime R&D efforts resulted in an increase in the adaptation of technology for the military. This increased pace instigated the need for more involvement by civilian and academic institutions to keep up with the rising R&D workload of the period. At Morris Dam, the increased workload was linked to its role as a support facility to NOTS Pasadena. In the late 1940's, NOTS scientists did testing on the anti-submarine projectile, Weapon A, at Pasadena and Morris Dam. The success of Weapon A led to NOTS Pasadena's development of rocket-assisted torpedoes in the early 1950's. BuOrd assigned many new projects in the 1950's to the facilities at Pasadena and Morris Dam including the Mine Mk 24 and Torpedoes Mk 13, Mk 25, Mk 32, Mk 41, EX-8, Mk 43, and Mk 44. Many of these weapons and systems would see use in the Korean conflict. Others were responses to needs of weaponry for new technologies such as helicopters and nuclear powered submarines (NOSC 1991:36,51).

Recognized as the top R&D facility for underwater weapons, the commanders of NOTS transferred the entire Underwater Ordinance Department to Pasadena and Morris Dam by 1952. During the late 1950's, NOTS scientists and engineers developed and tested many new and important weapons and systems at the Morris Dam installation. In 1956, NOTS Pasadena began work on the Antisubmarine Rocket (ASROC), a rocket propelled weapon able to fire a nuclear depth charge or homing torpedo. They also did research for the Polaris missile systems for nuclear submarines and in 1958, began to develop the new Mk 46 torpedo. The Mk 46 would become the main lightweight torpedo for the United States and its allies during the Cold War period (NOSC 1991:36,51). Between 1953 and 1959, the Navy constructed over 20 new support structures and testing laboratories on the peninsula (BuOrd/PWD Drawing MD241/-1 1959). Although the need for air-dropped torpedoes was diminished in the new jet and nuclear-age warfare, the VAL still saw over 1,100 test firings between November 1951 and February 1959 (VAL Launching Records 1950-1951; VAL Data Sheets 1959-1975).

The 1960's changed the role and structure of the U.S. Navy R&D. The Navy's plans called for consolidation ot their operations at their individual testing tacilities as well as management being reorganized along corporate lines. Rapidly changing technology altered the type of work conducted at the laboratories. Solid-state electronics and digital circuitry brought the U.S. Navy into the early computer age. The nuclear submarine fleet brought out new priorities for the torpedo program and pushed the development of the Mk 46 lorward (NOSC 1991:58,87).

The activity at Morris Dam changed according to the developments in the U.S. Navy R&D. The majority of the torpedo work during the 1960's focused on the Mk 46 and the ASROC system. The Mk 46's specialized homing system made it the perfect lightweight torpedo. Not only could the torpedo be launched by aircralt but by ASROC, helicopters and surlace ship launchers (NOSC1991:87). Even with this work, the torpedo program for the U.S. Navy had become less of a priority than it had been during World War II or the early Cold War. The drop in use of the VAL and an added emphasis toward the propulsion lab and test pits reflected this change. Whereas in the early 1950's the VAL averaged 35 firings a month, in the late 1950's the average was down to 12 a month. By the early 1960's, the firings averaged roughly 35 a year (VAL Launching Records 1950-1951; VAL Data Sheets 1959-1975). This drop in activity led to maintenance problems with the VAL. In December 1965, J.H. Taber, the head of maintenance tor Morris Dam, called for a complete overhaul ot the VAL systems due to recent troubles encountered during attempted tirings (Taber 1965).

In the late 1960's, the Naval Material Command moved to consolidate their 15 research laboratories into nine more complete facilities. The U.S. Navy deemed the Pasadena facilities to be inadequate to fultill the Navy's research needs as a separate facility. On July 1, 1967, NOTS Pasadena merged with the San Diego based Navy Electronics Lab's Undersea Technology Group to form the Naval Undersea Warfare Center (NUWC). A year later the Navy transferred the NUWC otticial headquarters, along with much of the personnel, to San Diego. This consolidation was a prototype for the "core" laboratory that the Naval Material Command hoped would allow the scientists and engineers to work closely on adapting new anti-submarine detection and weapons systems in the age ot emerging computerization (NOSC 1991:66).

The consolidation ot the Pasadena facilities into operations at San Diego continued into the early 1970's. The NUWC underwent several name changes during this period culminating in 1972 as the Naval Undersea Center (NUC). In May, 1974, NUC Pasadena was disestablished and all tunctions and personnel transterred to San Diego. The Morris Dam facilities were now under direct command from San Diego. Although the NUC continued work on new advanced lightweight torpedoes such as the Mk 50, the operations at the facility slowed (NOSC 1991:92). From 1968 to 1972, NUWC technicians launched the VAL just 23 times (VAL Data Sheets 1959–1975). Still, the scientists and engineers at San Diego had not completely overlooked the Morris Dam facilities for future use. In 1968, the NUWC had a large report prepared to standardize the methods and procedures for compiling and analyzing data from VAL tests (Stephens 1968). From January 1973 to January 1975, the NUC engineers tired the VAL 56 times during testing of the new Mk 50 torpedo (VAL Data Sheets 1959–1975). Former employees and other Navy personnel remember that although the VAL sat relatively quiet during this period, technicians used the propulsion labs and test pits regularly (Harmon, personal communication 1993).

In 1977, the NUC and the Naval Electronic Laboratory Center (NELC) merged to form the Naval Oceans Systems Center (NOSC). This merger provided for the complete consolidation of the research tacilities at San Diego. In the early 1980's, the merger proved even more important in obtaining larger funding for more comprehensive R&D work during the military-industrial buildup of the Reagan Administration. As such NOSC served the Navy with state-of-the-art equipment for systems testing and development (NOSC 1991:110).

By 1988, NOSC's workforce numbered over 3,000 full-time civilian employees and 262 military personnel. NOSC's primary facilities in San Diego were complemented with a laboratory at Kaneohe Bay, Oahu, Hawaii; sea ranges at San Clemente Island; an Arctic field station at Cape Prince of Wales, Alaska; and the test range at Morris Dam. The Morris Dam tacilities at the time included the VAL, the slingshot launcher at the SCR, a helicopter range for torpedo drops, a propulsion laboratory, static test cells and a polymer tlow tacility (NOSC 1988). In 1993, the Navy targeted the Morris Dam Test Range for closure. In June 1993, Navy technicians completed the tinal testing operations, the tacility closed, and all personnel transferred to San Diego (Harmon, personal communication 1993; Willis, personal communication 1993).

In summary, the Morris Dam Test Facility is linked to the tremendous growth of the military-civilian defense complex in southern California in the mid-twentieth century. The establishment of a consolidated, organized effort to link the scientific and military R&D communities in World-War II helped establish the Morris Dam facilities. Under NDRC, OSRD contracts, and the California Institute of Technology, scientists built and developed testing facilities for R&D of weapons systems at Morris Dam during World War II. The testing resulted in improvements that made important contributions to the United States war effort. These improved weapon systems brought success to the military on both fronts of the war and helped convince the Navy of the value of full-time R&D for the nation's defense.

Directly after the World War II, the U.S. Navy took over the Morris Dam facility and placed it under the command of the recently established NOTS. Under this command, more funding and support helped create the VAL and more elaborate testing facilities for underwater ordinance systems. During the Cold War years of the 1950's and 1960's, the Morris Dam facility worked on numerous new weapons systems and general research as an annex of NOTS. In the late 1960's, the Navy transferred the command ot Morris Dam to San Diego and a slow decline in the use of the facility continued until its closure in 1993. The Morris Dam Test Facility reflects the great efforts to mobilize and fund the nation's military defense during World War II and the Cold War years. The facility helped to synthesize the work of civilian and military engineers and develop the R&D complex that exists into the 1990's.

DESIGN AND CONSTRUCTION

In the early period of MDTF, design and construction was very functional and standard for the time frame. No unique structures or circumstances required any unusual design or construction. The main emphasis was to achieve an expedient solution to an existing problem. Theretore, construction was quick and simple consisting ot wood-trame structures erected on concrete slabs with moderately sloped composition roofs. This type of utilitarian design and construction continued throughout the 50 year span of the facility. The major exception to this was the Variable-Angle Launcher (VAL).

Due in part to the physical characteristics and location of the site, the VAL's unique structure caused many unusual and interesting challenges during design, fabrication and erection. Investigations and preliminary studies were made into each aspect of the VAL. Functional requirements determined many of the parameters needed tor each component of the design. Numerous launching methods and locations were analyzed to find the most feasible solution. The end results tavored a fixed-location, variable-angle launcher situated adjacent to the Fixed-Angle Launcher (FAL) at Morris Dam Reservoir. Construction plans were prepared during 1946 and 1947. In April 1946, construction began. On May 7, 1948, the VAL was otficially dedicated and fired. With the exception of some instruments, construction was complete in September 1948.

Before starting the design ot the VAL, a detailed study was made of functional requirements. The study was based on previous hydrodynamic investigations ot water entry and underwater behavior of aircratt torpedoes and the foreseeable higher speeds of military aircratt. Requirements included: Projectiles with body diameters up to 36 inches and maximum weights ot 4,000 pounds, velocities of 800 feet per second, water entry angles from 10 to 40 degrees, the ability to control attitude, pitch and yaw during tlight (best control with minimum 100 toot and maximum 300 foot tlight), and a minimum firing range of 300 feet wide by 3,000 teet long with a depth of 120 teet minimum and 200 teet maximum. 120 feet was the estimated maximum depth of a torpedo dive and 200 feet was considered the maximum depth for dive personnel to recover projectiles.

Studies for the type of launcher that could produce variable-angle, high speed torpedo launchings while maintaining identical parameters concluded that a fixed-location launcher possessed numerous advantages over aircratt drops. In addition, knowledge of the exact point of entry allowed better recordation with photographic equipment, trajectory nets, hydrophone and sonarbuoy ranges and other instrumentation. A tixed launcher also permitted higher launching velocities than the fastest aircraft in current use.

Selection of the launcher site was the next task. With an available range of 600 teet by 3,000 feet at an average depth of 150 teet, an existing 1:1 slope at the selected site, and a satisfactory height of the peninsula, the most suitable site proved to be adjacent to the existing FAL at the Morris Dam Reservoir. Additionally, it was readily accessible from other facilities in Pasadena, had available stores, accommodations, railway connections six miles away in Azuza and the climate provided for year-round operation with good conditions for photography. No other site investigated so completely filled the requirement as did the MDTF.

Once the site was selected, preliminary designs began to explore the possible structures and their costs. A tube, equal to the diameter of the torpedo, was selected to support the projectile during the acceleration period. The launching tube would be supported by a steel "bridge" 300 feet long. A bridge type structure was considered excellent trom the standpoint of rigidity due to only small deflections introduced by varying the angle of the bridge.

Three general schemes offered sufficient promise to warrant preliminary designs and cost estimates: a "tower system", a "dual-rail launcher", and a "barge-type launcher". (See Figure #4, 5, and 6). Operational characteristics and miscellaneous data were analyzed for all three systems. However, lower first cost, suitability for construction at the site, and maximum operational flexibility dictated selection of the third plan, the barge-type launcher. Estimated cost of construction $511,000.

The selected site possessed a number of natural advantages. However, the stability of the rock slopes and the peninsula itself would have to be proved prior to beginning construction. Earlier studies of the surrounding area had shown rock slides and unsatisfactory foundation conditions. A comprehensive geological exploration program was undertaken. Two points of major concern were evident from the explorations: the possibility of a surface rock slip and the possibility of a slip along a deep circular arc within the peninsula.

In order to insure surface stability, it was recommended that the loose material be keyed into the firmer underlaying rock. This was accomplished by shallow grouting under the launcher pad, deep grouting at the base of the launcher pad (extending below the bottom of the reservoir), and keying the launcher slab to the rock slope. Figure #7 shows the extent of exploration, drilling and grouting. The deep circular arc was also closely analyzed. By considering of the character of the rock and the fact that the lines of stratification dipped steeply into the hill and cut across the arc at a sharp angle, the danger of a slip along this line was deemed to be very minimal.

Foundation analysis and design for the launching slab assumed a concrete slab 4 feet thick and 40 feet wide at a 45 degree angle on the southwest slope of the peninsula. The deadweight alone would produce a tangential component along the surface of 600 pounds per square foot. It was felt that the natural keying of the concrete slab into the irregular surfaces of the scaled and cleaned rock would be sufficient to carry this load. However, to provide an added factor of safety, it was recommended that additional keying be utilized. The method used consisted of cutting "benches" or steps the full width of the slab at suitable intervals along the slope. Additionally, 1" diameter reinforcing rods were drilled and grouted into the rocks at a 45 degree angle.

At the top of the 45 degree slope, at elevation 1,300 feet, flatter slopes gradually rounded off to the top of the peninsula at about 1,357 feet. A cellular structure was designed to cross the ridge and connect to the counterweight slab on the northeast slope of the peninsula. Two walls located directly under the rails of the launcher and counterweight car provide the form of the structure. Rooms are constructed between the walls and step down with the grade on both sides of the ridge. A safe bearing value of 6 kips per square foot was recommended for footings near the top of the ridge.

The junction of the cellular structure with the launcher slab required special treatment. A choice was made to construct the two as an integral unit without an expansion joint to maintain the continuity of the slab for the full height of the structure. As an anchor to resist sliding and to stabilize the upper end of the launcher slab (where the walls began to take up the loads), it was recommended that a step be made the full width of the slab. The horizontal distance into the rock was to be 5 feet. As no expansion joint was to be provided, the step would prove particularly desirable in reducing possible excessive pressures from shrinkage forces on the footings at this point.

The initial excavation for the launching slab was done using a 2 yard dragline from a bench cut near the top of the slope. Benches and stepped footings were cut into the 45° slope using pneumatic tools. All material excavated, approximately 5,000 cu. yd., was dumped into the reservoir at the toe of the slope. Final surface cleaning was done by hand labor and sluicing before pouring the slab.

In general, the principal reinforcement consisted of 1¼" square bars on 6 inch centers in the top and 1 inch round bars on 6 inch centers on the bottom placed transverse to the slab. Longitudinal reinforcement consisted of 1 inch round bars on 16 inch centers, both top and bottom. The lower mat of reinforcing steel was fitted to the shape of the slope. The upper mat was set to a specified grade. Both mats were supported by reinforced steel legs welded to the mat with the lower ends set in crevices in the rock. Where possible, the mats were tied to steel dowels previously grouted into the slope.

On the northeast slope of the peninsula, a completely different set of circumstances dictated the design of the counterweight slab. The soil along this slope was partially overlayed with a red clay material from a highway cut. This red clay overlayed firm decomposed granodiorite which gradually merged into fractured and badly broken, but well consolidated rock. The rock ranged from 2 feet to 22 feet below the surface. It was recommended that wherever the slab departed from the soil it would be carried on walls. The wall footings would extend 2 feet minimum into the decomposed granodiorite or red clay. The wall would also be constructed in uniform horizontal steps. All of the material was believed capable of carrying the slab and the counterweight car without appreciable settlement. It was necessary for drainage on both sides of the slab to avoid water accumulation seeping into the slip planes and making the slope unstable.

A minimum thickness of 14 inches of reinforced gunite was used to construct the counterweight slab. Gunite was chosen over concrete based solely on cheaper construction costs. The counterweight slab posed different conditions at the junction of the slab to the headwork structure. An underpass cut the wall structure nearly into two pieces. Cracking at this juncture was certain to occur. There is also a transition from firm bearing on rock to bearing on clay and decomposed granodiorite, along with a transition from a heavy concrete structure to a lighter gunite slab. A joint was desirable and complete separation was also considered. It was agreed to provide a joint at the underpass location with the slab steel running continuously through the joint to tie the whole structure together. A three foot horizontal step was also added to thicken the slab at the point where it passes from grade to being supported by two walls (similar to the launcher slab).

In an effort to keep the working surtace free of rebound, the contractor chose to start guniting from the top of the slope. Despite his efforts, re-bound accumulated on the slope. Placing the gunite was made especially difficult because of the heavy mat of reinforcing steel and wood templates used for spacing the rail anchor bolts. A total of 210 cu. yd. of gunite was placed. Curing was maintained for six days by water sprayed on the slope.

It was expected that the gunite slab would meet the specified strength of 3,000 psi at 28 days since as the gunite test cylinders made during the placing of the slab tested satisfactorily. The test cylinders, 6 in. diameter and 12 in. long, were shot into a ½" mesh hardware cloth cylinder. The cylinders indicated an average 28-day strength of 3,840 psi. Four inch cores taken from the cured slab indicated an average strength of only 2,100 psi at an age in excess of 28 days. The cores also showed a deficient bond between layers of gunite and between gunite and reinforcing bars, as well as extensive occurrence of sand pockets.

Despite the deficiencies of the gunite, it was thought that the strength of the slab was sufficient to serve its purpose, and the type of failure that might occur would be progressive cracking or disintegration which could be observed. Such failure of the slab would not endanger the structure, and repairs could be made at a later date if necessary. In the light of the Government's urgent need for the completed project, the slab was accepted.

The counterweight car was designed to operate on a straight track using twenty railroad wheels and 10 axles mounted in simple pedestal jaws rather than trucks. The bearings are Timken Roller bearings with journal boxes of usual design. Wheel assemblies were spring-mounted to insure uniform load distribution. Rails chosen for the track weigh 90 pounds per yard and are standard gage. The rails are anchored by pairs of one inch bolts spaced on three foot centers.

The steel railroad car chassis provided anchorage to the car body and served as the bottom form. The car body was constructed of "heavy" cast-in-place concrete made by replacing part of the rock aggregate with scrap steel nuts, bolts and punchings. The concrete mix was designed to include 3,200 pounds of scrap steel per cubic yard producing a theoretical density of 225 pounds per cubic foot. Three open compartments were provided inside the car for additional "heavy" concrete ballast blocks or pig iron ballast as required. The center of gravity of the fully loaded counterweight car is 6.7 feet above the rail which favorably compares with standard railway rolling stock. Stability of the car during an earthquake is also ample. A static lateral force of 35 percent of the fully loaded weight is required to overturn the car.

The 50 ft. x 10 ft. all-welded counterweight car chassis was fabricated in the contractor's shop. The wheels, axles and journal boxes were mounted on the chassis in the shop. This assembly was transported to the launcher site by truck and unloaded by a 60-ton speedcrane that was located on the west side of the structure. During the process of setting the car chassis on the rails, the crane overturned and dropped the car to the ground on the east side of the slope. The car broke loose, rolled down a ravine and plunged into the reservoir. Navy divers located the car in 105 ft. of water, almost completely buried in mud.

With the aid of blocks and tackle attached to the connecting bridge and mounted on two barges, the chassis was retrieved from the mud and towed to the erection area. It was then cut in half with an acetylene torch and hauled back to the contractor's plant for clean-up and minor repairs. Later, the car was returned to the counterweight ramp where it was installed on the rails in two pieces. The two sections were then welded together.

The general siting and arrangement of the various components of the VAL are shown in Figure #8. Basic dimensional data for the major components are shown below.

LAUNCHER BRIDGE

Length	300 ft.
Width (chord centerlines)	22 ft.
Height (chord centerlines)	35 ft.
Vertical angle	0 to 40 deg

BRIDGE SUPPORT CARRIAGE

Wheelbase (pin to pin)	33 ft. 9 in.
Wheel gage	21 ft. 2 in.

CONNECTING BRIDGE

Span (heel to heel)	95 ft.
Span (barge to barge)	60 ft.
Width (top chord centerlines)	4 ft.
Width (bottom chord centerlines)	20 ft. 9⅛ in.
Height (in place of truss)	21 ft. 5 in.

BARGES

Length	60 ft.
Width	35 ft.
Depth	12 ft.

LAUNCHER SLOPE

Length (including portion on the concrete superstructure)	332 ft.
Width (including cantilever slab for supporting projectile car rails)	37 ft. 9 in.
Design thickness	4 ft.

COUNTERWEIGHT SLOPE

Length (including part on concrete superstructure)	352 ft.
Width (including cantilever stab for supporting personnel car rails)	19 ft. 10 in.
Design thickness	14 in.

CONCRETE SUPERSTRUCTURE

Length	260 ft.
Width	22 ft. 8 in.
Elevation, top	1,387 ft.

Design of the steel structures began with exploration of welded verses riveted construction. A major prerequisite was that of rigidity. The launching tube had to be accurately aligned prior to each launching. Supports for the tube were made adjustable, however, due to the number of supports required for rigidity, aligning of the tube was a long and tedious process. The desirable solution was for a very rigid structure with a relatively small dead load deflection to eliminate frequent realigning of the tube. Preliminary studies showed that a riveted structure would weigh appreciable more than a welded structure (detailed studies estimated an increased weight of 60%). This increase in weight provided no increase in rigidity and would create greater deflections.

Welded design for this size of structure would be based on the most recent developments in welded detailing. This detailing would involve extra expense due to the fact that most steel fabricating plants were unfamiliar with the new procedures. It was accepted, but not proved, a welded structure would cost as much as a riveted structure despite the savings in weight. Appearance and safety were improved on a welded structure by minimizing sharp edges and corners. Actual rigidity of welded joints had not been analyzed completely enough to determine the full value of faired or "streamlined" joints. Complete and absolute continuity inherent in welded construction was considered to be an important factor, especially for a structure where highly indeterminate dynamic loads could be accidentally introduced at any time. Full continuity implies high redundancy which exhibits high ultimate strength since all structural elements are interacted prior to a collapse. Welding of the bridge structure was the construction method chosen.

The welding was designed in conformance with the specifications of the American Welding Society, 1941 Edition. However, final details were checked against the 1947 Edition. The main change in the specifications was the use of the same stress in full butt welds as in the parent material. This resulted in considerable economy of material and labor for main member splices and connections at joints.

The layout, arrangement and controlling dimensions of the launcher bridge are shown on Figure #14. A full analysis of the proposed structure was calculated. Loads on the bridge were determined carefully and included: dead load, fixed live load, recoil and counter-recoil loads, wind loads, seismic loads and torsional loads. In total, thirteen basic loading conditions and twelve combined loading conditions were analyzed. To confirm the validity of the analysis, an approximate scale model was constructed of brass and a torsional analysis made of the model. Physical torsional tests of the model gave results almost identical to the analysis.

The particular orientation of the truss members permitted excellent streamlining of the joints with respect to the major stresses. All plates introduced into re-entrant angles were snipped to break the welding around the corner and eliminate possible stress concentration at that point. The radii used in streamlined fittings were never less than 3 inches and usually about 6 inches. In some cases, the radii were increased to extend the haunch effect and avoid excessive size throughout a long member. All major welds were butt welds with double bevels on both members to obtain good penetration and fusion. The use of 14-inch members on the truss permitted a wide range of weight and strength while retaining the simple details of alignment and connection. Typical welded connections and assembly of the bridge structure are shown in Figure #17. The main reaction girders were welded, tapered sections designed to sustain the applied loads without introducing excess dead weight. The initial pressure tank installation (approximately 90,000 pounds of dead load) introduced eccentric lateral loads on horizontal members of the transverse frames when in the inclined position. This required special connections and local strengthening of the supporting beams.

During the welding of the lower chord structure, radiographing of welds was started. A number of welds were found which were not satisfactory because they contained slag deposits or hairline cracks, or because full penetration of the weld was not accomplished. All deficient welds were chipped out and rewelded. To improve the welding, a record was kept of the work done by each welder. Also, the inspector approved the back chipping of each weld before the welder could continue. Radiographs of welds made after this system was put into effect indicated no poor welds.

The launcher bridge connects to the launching ramp via the bridge support carriage. This carriage rest on rails attached to the launching ramp slab. The general features and basic dimensions for the bridge support carriage are shown on Figure #12. The unique design of the heavy rail section is shown on Figure #16.

During the launching of a projectile, large forces are transmitted through the bridge support carriage to the rails and the foundation slab. Seven inch diameter pins lock the carriage to the rails and provide for the transfer of force. In order to achieve the desired force distribution and to provide for seven inch holes and anchor bolts, a stiff and heavy rail section was required. Lateral stiffening webs were provided to give lateral stability and to transmit transverse components of the force. Arc welding was used in the rail construction.

The rails are anchored to the launcher slab by 2-inch bolts on 18-inch centers. Bolt holes in the base plate of the launcher rail were made ¼ inch oversize to facilitate alignment of the rails. The anchor bolts were set in the concrete by use of a steel template fitted into the top form used in pouring the slab. A recess, which later was filled with grout, was formed in the concrete under the rails to provide for precise alignment. The grout was placed by sealing the space at the edges of the rail base plates with stiff mortar and then pouring fluid grout into the remaining space under the rails through pipe-tapped holes in the base plates. Shear lugs welded to the base plate of the rails thus were embedded in the grout to transmit both longitudinal and transverse shearing forces.

The bridge support carriage structure is supported at four corners on four-wheel trucks, each with independent coil springs. The design was fabricated from standard steel shapes and plates. The carriage consists of a heavy structural steel space framework. A central pivot provides for movement and load transfer between the bridge and carriage. A pair of shoes, under the outer corners of the bridge and sliding on horizontal curved rails, were designed to transfer the vertical loads. The pivot transfers the horizontal loads.

Four hydraulically operated pins, one for each wheel truck, lock the carriage to the rails. These pins engage sleeves in the rails to provide a positive transference of loads in a vertical plane through the rail centerline. All lateral loads are transferred through shoes attached to the inside plates of each wheel assembly and bearing on the inside lower edge of the main rails. The locking pins are solid steel, guided by steel tubes attached to the inside of each wheel assembly.

Designed to serve a multiplicity of functions, the bridge support carriage was fabricated as simple trusses connected by rigid decks and plates. The platform receiving the reactions from the launcher bridge is made of heavy steel plates welded to form a rigidly reinforced deck. The side plates extend down from the back of the platform and are butt-welded to the outer side plates of the upper wheel assemblies. The side frames are simple trusses which were also designed as rigid frames in bending. Lateral loads are transferred to the wheel assembly by two systems of diagonal bracing.

The wheel assemblies were built up from steel plates. The side plates are one inch thick, with top plates and internal and external bracing to carry the loads and permit action as rigid units. Each assembly has two axles, which carries two standard 33-inch railroad wheels. The ends of each axle are mounted in standard railroad roller-bearing journal boxes, which are guided normal to the rails. A spring-jack assembly on top of each journal transfers the structural loads onto the axle and wheels. An adjustment was provided in the spring jacks to allow for variations in wheel loading, thus making it possible to maintain the relationship between the locking pins and the sleeves in the main rails.

A beam, for attachment of the cables connecting to the counterweight car and main drive, is located between the upper wheel assemblies. This "cable beam" is made from steel plates welded to form a heavy section. To provide for transfer of the cable loads into the carriage structure, two additional heavy built-up steel members were attached at the third points of the cable beam and to the lower wheel assemblies.

The muzzle end of the launching bridge was supported by two floating barges connected by two simple five panel trusses. Refer to Figure #15 for the general arrangement and basic dimensions of the connecting bridge, barges and launcher bridge.

Designing the barges to meet the requirements of static stability proved to be simple. However, design complications resulting from dynamic wave loads and potential accidental damage to the barges were carefully investigated. Loads applied to the connecting bridge were closely related to the hydrostatic and hydrodynamic action ot the barges. Because of the size and mass of the barges, and the protected position in the reservoir, no appreciable movements due to reservoir waves or entry surges were to be expected. However, steady waves of relative small amplitude and proper trequency might build up large barge motions.

Analysis of the existing design resolved the wave motion problem into that ot a resonance phenomena. A comparison of nine natural frequencies showed only counterroll within the critical range. Two possible methods were reviewed to combat this problem. The first was to change the barge geometry, but it was tound that any changes in this direction were not teasible. The second was to change the torsional resistance of the connecting bridge. The original design had a torsional rigidity tactor ot 57,000 foot-tons per radian. The new design increased this factor to 275,000 foot-tons per radian reducing the period of counterroll from 1.2 seconds to about .87 second.

Structural steel tabrication of the connecting bridge trusses was detailed using faired or "streamline" connections similar to the launching bridge. The pillow blocks, which receive the launcher bridge end pins, are large castings resting on heavy weldments on the top chord of the connecting bridge. The castings were bolted to the weldments. Heavy sheets ot formica insulated the pillow blocks trom the end pins.

Design and construction of the barges followed the conventional practices developed in the shipyards during the war. Riveted construction could have been used but welded construction possessed a number ot advantages. Each barge is divided into twelve compartments to minimize the effects of accidental damage. Fill and drain pipes into each compartment permit a shift of ballast to control trim and compensate for changes in loading on the launcher bridge.

Additional structures were designed and built in the vicinity of the VAL that supported the operation and recordation of the tests. The control station, located just southeast of the VAL, and three tixed camera stations, located along State Highway 39 west of the firing range, are built of reinforced concrete. The floor slab, walls and roof are all of cast-in-place concrete construction. The doors and camera ports are metal-sheathed wood for maximum protection. Convex bullet proof glass, 2⅛" thick, was used at the control station windows to protect against damage from possible accidents.

A sideview camera car was constructed near water level on the west bank ot the reservoir. The camera car is a wood-frame structure built onto a railroad car chassis. The car travels on light rails of standard railroad gage. The track is supported by two bridges, 324 feet and 200 feet long. The trusses of the longer bridge are continuous over piers and were made from surplus Army H-10 box girder sections. The shorter bridge has two spans, one 162.5 teet and the other 37.5 teet. The longer span was designed as a queen's post truss. The top chord was made of surplus Army H-20 box girder sections, the verticals of H-10 box girders and the lower chord members and diagonal bracing ot round rod. The shorter span was made of H-10 box girder sections.

During construction, Islip Canyon, a peninsula about ½ mile north of the site, currently the heliport, became a secondary fabrication yard. The area was accessible from the state highway and was graded to furnish a working area adjacent to the water. Final assembly for the steel sections of the VAL were completed here. Delivery to the test site was by barges on the reservoir.

Due to the location of the test site, physical features of the construction site and size of the structure, the fabrication and erection of the VAL posed many unique problems. The engineers and contractor proposed, designed and constructed many unique solutions to counter each problem.

Forming of the launcher slab would have been costly and hazardous on the 45 degree slope if done in the conventional manner using wood framing and plywood forms. To eliminate some of the difficulties the contractor built a moveable steel form. The structural steel form consisted of a channel-shaped steel faceplate backed by steel beams and reinforcement with wheels at the four corners.

The assembly was rolled up the slope on rails set on heavy timbers just beyond the side limits of the slab. Holes were drilled in the faceplate for the accurate placement of the launcher-rail anchor bolts. The steps, curbs and launcher-rail recesses were also cast by the steel form. A 25-foot section of slab could be poured at each setting of the form. The form was moved, set and the concrete placed in a period of two days. Calcium chlorine was used as an admixture to accelerate setting.

To move from one pour to the next, it was necessary to lift the form off the anchor bolts. This was done with hydraulic jacks located near the wheels at the four corners. The jacks also were used to set the form to accurate grade before anchoring it to the mat of steel reinforcing. To insure exact spacing of the main rail anchor bolts, the lower line of bolt holes on the form were placed over the upper line of bolts in the previous pour. This overlapping also served as a good grade control for the bottom of the form. The form was set to line with a transit before each pour. The form was pulled up the slope using the tagline of a crane.

A one-cubic yard concrete mixer was set on a bench cut at the top of the slope. A steel car of one-cubic yard capacity was set on rails attached to the top mat of slab reinforcement and was moved up and down the track by a winch anchored to the apex of the main superstructure. The mixed concrete was poured into a one-cubic yard bottom dump bucket. The bucket was swung by a crane over to the ramp car into which the concrete was dumped for transport to the pour. The car dumped the concrete into sheet-metal troughs for lateral distribution in the form. Approximately 1,640 cubic yards of concrete was poured by this method.

Another unique operation was placing the rails for the support carriage. The rail sections weighed about 4½ tons apiece. The rails were loaded on a barge at Islip Canyon and moved to the bottom of the launcher slope. The two bottom rails were set on the anchor bolts from the barge. The remaining rails were then placed one at a time using a pneumatic-tired car built to straddle the anchor bolts. The car was equipped with chain hoists for raising and lowering the rails and was moved up and down the ramp by a winch. Under precise instrument check, the rails were set to alignment and grade. Atter setting, stift grout was placed under the rail base edge. Then wet grout was forced under pressure through holes in the base plate into the recess beneath the center portion ot the base plates. Shear lugs welded to the underside of the base plates were thus bonded to the concrete slab.

Fabrication and erection of the steel components required shop work, transportation, field work and tinal assembly at the site. Generally, the steel structures were shop-tabricated into sections as large as could be transported. Once delivered to Islip Canyon, the tinal field tabrication and erection completed the individual components. Final assembly occurred from barges atter floating sections from the Islip Canyon peninsula to the VAL site.

Bridge Support Carriage:

The bridge support carriage was field erected onto a rail sections at Islip Canyon near the waters edge. The contractor poured four concrete footings on which two rails were bolted similar to the rails on the slope. These rails contained the pin holes which spaced the wheel assemblies. The four wheel assemblies were set on the rails and the pins put through the holes to provide a lock tor the assemblies; the remainder of the carriage was then assembled.

Transportation to the launcher slope was accomplished by mounting two rails on a pontoon barge with ends extending beyond one end ot the barge. Two 7½-ton gasoline winches were welded to the barges outside the gage of the rails. The overhanging ends of the barge rails were secured to the reservoir end of the erection rails by pins and the assembled carriage pulled aboard the barge. The carriage was then transported down the reservoir to the foot of the launcher slope.

The overhanging ends of the barge rails were pinned to steel anchor blocks previously set on concrete bases at the bottom ot the main launcher rails. A 50-ton block was anchored up the slope to each rail and one on each upper wheel assembly. A single cable was reeved from one winch through the four blocks and to another winch, thus providing adequate drum capacity. The pull of the two winches was utilized to draw the carriage onto the launcher rails, where it was anchored with the pins. The contractor completed fabrication of the carriage on the slope.

Barges and Connecting Bridge:

Due to the limiting widths of road cuts on the State Highway providing access to the MDTF, it was necessary to transport each barge to the site in two sections. This was accomplished by designing a transverse joint in each barge and transporting each half to Islip Canyon. The two sections were then field welded together. Completion of the deck work was made atter the barges were atloat.

The connecting bridge is a 95-ft. span, all-welded structure connecting the two barges and supporting the muzzle end of the launcher bridge. The connecting bridge contains about 38½ tons of structural steel. The trusses were fabricated in the contractor's shop in three sections, consisting of a 34-ft. center section and two end sections of 30½ ft., and were erected and field-welded in place on the barges at the erection area.

In general, steel members which were under 3/8 inch in thickness were butt welded together with the members beveled at 60° on one side only. Members 3/8 inch and over were beveted at 60° on both sides. All beveling was done with a cutting torch.

Field assembly started at the site by having the two barges pulled up along side of each other. The first 30½ ft. section of truss was set by a crane in the two supports on the one barge and bolted to them. The center 34-ft. section was then set on shoring on the second barge and, atter alignment, tack-welded to the end section. After setting and bolting the end section ot the other truss to the barge, temporary bracing was welded to both trusses to maintain alignment. The lower chord horizontal diagonal bracing and the vertical diagonal bracing were then set into place and tack-welded to the first section. The center section of the other truss was set into place and, after alignment, tack-welded onto the structure. Atter carefully checking alignment in all directions, the members were completely welded together.

After completion ot the welding, the barges were moved apart and the two remaining end sections of the trusses set on shoring and welded to the center sections. The end bracing section and the remainder ot the lower chord bracing was then welded to the structure. The barges were pulled apart to the required spacing and the end sections bolted down to their supports. The welds were wire-brushed and primed with a coat of red lead primer and the whole structure was then sprayed with a coat of aluminum paint.

Launcher Bridge:

The launcher bridge, as previously described, is a 300 foot span, all-welded structure. The main trusses are twelve-panel pratt type with three-story, two bay, rigid transverse trames at each panel point. Most members were 14 inch wide tlange shapes, or equivatent sections made by welding together three plates. These substitute sections were supplied at the contractor's discretion because of long delays in the delivery of rolled shapes.

Three phases of fabrication occurred at the Contractor's shop. The first phase consisted of building the trames. The 14-inch wide flange shapes were torch-cut to length and assembled on the floor. The lower transverse member of the frame was not welded into the assembly, as it was to be assembled into the lower chord or deck assembly. During welding, the members were held in alignment by being tack-welded to the steel floor.

The second phase consisted of fabricating the lower chord. The lower chord or deck structure was assembled in the contractor's yard on a timber falsework built up so as to include the required camber. The deck structure included the lower chords of the trusses, the bottom members ot the transverse trames, the cross bracing and the deck support girders. Fabrication consisted of tack-welding together the wide tlange sections of the truss lower chords. The tower members ot the frames and the cross bracing were tack-welded into place. Alignment and camber were then checked before final welding. After welding of the full 300-toot lower chord structure, it was cut into sections approximately 50 feet in length tor transportation to the erection area.

The third phase consisted of cutting to size the members ot the upper chords, truss diagonals and upper cross bracing. All fabricated members were given one coat of red lead primer prior to transportation to the erection area.

At Islip Canyon, the lower chord sections were again set on a timber falsework with the calculated camber and tack-welded together. The transverse panels were then lifted into place, one at a time, and held in alignment with guys until truss diagonals and other members were tack-welded to hold the panels rigid. Succeeding transverse trames, truss diagonals, top chords and bracing were set in place and tack-welded. After caretul checking of the alignment and fabrication tolerances, the welding was completed. Approximately 251 tons ot structural steel were used to fabricate the launcher bridge.

Transportation of the completed bridge to the launcher site was accomplished by tloating the bridge down the reservoir on barges. The timber erection falsework was removed by jacking up the bridge, removing the talsework, and lowering the bridge onto two sets of rollers. The bridge was then rolled torward to bring the lower support pins over the pillow blocks on the connecting bridge. With the launcher bridge and the connecting bridge in position, ballast water in the barges was pumped out to bring the pillow blocks up to the lower pivot pins. The shore end ot the launcher bridge was then rolled towards the reservoir. A large pontoon barge supporting timber falsework was floated under the bridge, and the reservoir level was raised by discharging water from a reservoir upstream until the shore end ot the launcher bridge rose off the supporting rollers. The bridge was then floated down the reservoir to the launcher slope and attached to the bridge support carriage in a manner similar to the reverse of that used in launching the bridge.

The variety of challenges and the solutions provided during design and construction of the Variable-Angle Launcher deserve acknowledgement. The construction was under the jurisdiction of the Bureau of Yards and Docks of the United States Navy, with Captain H.L. Mathews acting as Officer in Charge ot Construction and Commander C.E. Langlois as Resident Officer in Charge of Construction. The design was the responsibility of the Development Engineering Section of the Underwater Ordinance Division of the U.S. Naval Ordinance Test Station, China Laile, California. In charge of design were W.H. Saylor, Head of Underwater Ordinance Division, and J.H. Jennison, Chiet Engineer along with J.H. Wayland, Chief Physicist, and F.C. Lindvall, Consulting Engineer.

Consultants employed on the project were: Coast Marine Engineering Company; F.J. Converse, Consulting Foundation Engineer; Frank G. Denison, Jr., Naval Architect; V.P. Pentegoft, Consulting Geologist; Quinton Engineers, Ltd.; and N.D. Whitman, Jr., Consulting Structural Engineer.

The General Tire and Rubber Company of California was the prime contractor; J.E. Keenan, Engineer in Charge. Major subcontracts were awarded to United Concrete Pipe Corporation for steel structures and to Norman I. Fadel for concrete structures.

VAL OPERATIONAL PROCEDURES

Procedure for a launch of the Variable-Angle Launcher varied little over its 45 year life-span. However, the time involved preparing for each individual launch had many factors that varied the schedule greatly. Some test shots could be completed in less than a day. While other test shots could take many days to prepare. The most undetermined factor was in the preparation of the torpedo itself. Preparation of the torpedoes and test dummies took place at the Torpedo Shop, just to the east ot the VAL in the torpedo assembly room.

Projectiles were modified, pieced together, and re-assembled for launching in the Torpedo Shop. A twelve man crew worked to prepare projectiles fired through the VAL. A full machine shop and welding shop was available along with a tool room, stock room and storage racks for torpedoes. After each launching, projectifes were returned to the torpedo shop tor instrumentation analysis and any repair work required.

Various recording instruments were installed inside the Torpedoes. One such instrument, a pressure plug, measured the peak pressure at various points on the nose ot the projectile by the detormation of a small copper diaphragm. Other instruments measured acceleration in various ways. The space-time instrument gives acceleration versus time data by means of a weight which can move along a linear track against the action of a spring. The weight carries one or more brushes which move across linear commutators. The step accelerometer gives similar information, but with less resolution, by means of a group of weights mounted on stitf springs. The weights are part of an electrical circuit, and each is adjusted so that it opens its contact at a ditterent value of acceleration. Peak accelerations are measured by deForest-type scratch gages and instruments utilizing deformation of lead BB shot by a small weight. The degree of deformation ot the shot indicates the amount of acceleration. (Smith 1952: 86-87).

Another internal instrument used for recording missile attitude was a gyroscope. By means of gyroscopes and a recording camera carried inside the projectile, it was possible to record angular motions during water entry and underwater flight. Ordinarily, two gyroscopes were used so that orientation about three axes can be determined from the recorded data. The gyroscopes are equipped with commutators which indicate angular motion in one-half degree steps. The record is obtained on continuous moving 16-mm film in the form of a series of dashes in step sequence indicating direction and angle of rotation. (JENINSON 1950: 44-45)

Depending on the type of instrumentation and the parameters being tested, torpedoes could be ready in hours or days. This included the time to make each instrument. All instruments used at the MDTF were made at the facility. After the instrumentation was installed, tested and double checked, the torpedo was placed on a rolling cart and wheeled out ot the assembly area.

Outside of the Torpedo Shop were scales used to weigh the finished torpedo. Two different weights were taken. A dry weight of the torpedo was needed for calculating the pressure and velocity of each test launch. Additionally, the torpedo was weighed in water to determine its wet weight. Atter the torpedo was weighed, it was rolled on its cart down the sidewalk to the VAL loading platform, adjacent to the southeast side of the launcher.

The projectile car was brought to the level ot the platform and the torpedo cart was rolled onto the car. The car was raised or lowered along the 45 degree launching slope to the level of the bridge support carriage upper platform. A three-ton overhead crane lifted the projectile onto the carriage deck and placed it on the projectile loader. The crane also positioned the projectile loader to align with the launching tube according to what angle the launching bridge had been set for the test shot. An hydraulic motor actuated a ram on the projectile loader which pushed the projectile into the tube. The projectile was held in place in the tube by a tension-link release mechanism which released just prior to the firing. A heavy steel hatch was closed and secured at the breach end of the launching tube. The bridge support carriage was cleared and the launch countdown could commence.

Smaller torpedoes were able to be shot in a larger diameter tube by the use of a sabot (pronounced sä bō). A sobot is simply a spacer built around the projectile to make it fit the launching tube. In the earlier days of the VAL, sabots were made of wood. This changed to styrofoam in the later years because it was a lighter and cheaper material. Sabots are made from a number of pieces held around the projectile by a strap. A blasting cap was timed to blow the strap off the sabot immediately after the projectile left the launching tube. The sabot then fell away as the torpedo continued on its flight (See Figure #22). The use of a sabots eliminated the need for various size launching tubes originally planned for the launching bridge. A second launching tube, 32 inches in diameter, was added in 1953 for projectiles larger than the 22½ inch launching tube originally built for the VAL.

One characteristic of range operations is the need to coordinate many remote instrument stations if test data is to be successfully recorded. Much confusion and delay can be caused by inadequate methods of communication. To avoid such difficulties, the Variable-Angle Launcher was provided with a well planned supervisory system of communication, centered in the Control Station. This station is located east of the launcher and commands a good view of the test range. Provisions had been made for easy oral communication and for a visual system of lights in the Control Station which indicated the state of readiness of remote instrument stations.

Thirty-two stations were represented by an individual red light prior to any launch. Each station must report as being ready with the corresponding light being switched to green before the final launch sequence could begin. Stations included all exterior recording devices such as motion picture cameras, acoustic hydrophone array, trajectory nets, as well as all safeguards on the VAL including the launcher bridge evacuation, quick acting valve oil level, safety interlock system and projectile car evacuation. After all 32 stations had reported in green, the projectile launch countdown would commence at "T minus 30 minutes".

The control room would begin the final series of warnings and communications prior to launch. At T minus 10 minutes, one long blast on the air horn alerted personnel to the nearing launch. For high velocity shots, any shot over 300 foot per second, the highway was cleared and closed off by the Highway Patrol. Road blocks were placed at the main gate and below the dam at T minus 5 minutes. At T minus 60 seconds, four short blasts on the air horn gave the final warning before launch. At T minus zero, the launch switch was activated and the launch occurred.

In all, a series of 41 procedures took place in the Control Station prior to any launch. Refer to Table 3-1, VAL Control Room Launch Procedures, taken from the operating procedures on the VAL (NOSC; 3-16 through 3-19). Five personnel worked in the Control Station but as many as twelve people were often present to observe the launch.

Before any launch of the VAL occurred, a meeting was held in the conference room to discuss the launch and procedures required so that everyone involved was aware of the expected conditions. In the earlier period of the VAL, numerous launchings could occur in a day. In the late 50's and early 60's, up to 35 projectiles were launched in a week. Typically this involved much planning and coordination. In the later years of the VAL, launching were not as common. As few as one launching a month became the average. Again, planning and coordination was a high priority to keep the operation safe for everyone involved.

Once a projectile had been launched, a series of different methods record the flight, water entry and subsequent water travel. Entry velocity, attitude, trajectory angle, angular velocity and acceleration in pitch and yaw are all important in providing estimates and predictions of missile behavior. Each VAL launch is recorded thoroughly with instruments that may include: the position interferometer, motion picture cameras, the acoustic hydrophone array and underwater trajectory nets. Each helped to record particular data that formed the overall review of any projectile launching.

The position interferometer provided data which allowed calculation of the acceleration and velocity of the projectile as it passed through the launching tube. The interferometer converted the tube into a cavity resonator. With a 394 MHz signal, resonance occurred every 24 inches as the projectile progressed down the tube. A radio frequency oscillator was connected by a coaxial cable to a coupling loop on the inside of the 22½-inch launcher tube breech door. A section of the coaxial cable was slotted so that a radio frequency signal sample could be taken and rectified by a crystal, producing a signal which was amplified to drive a recording galvanometer. When the breech door was closed, the tube formed a closed radio frequency signal cavity, and as the projectile passed through resonance nodes, there was change in the standing wave ratio on the transmission line which caused a corresponding change in the recorded signal. Thus, the projectile position could be determined with excellent accuracy. And velocity and acceleration could be easily calculated since an accurate time reference signal was recorded with the interferometer signal.

The muzzle velocity information derived from the position interferometer was augmented by extensive motion-picture camera coverage of projectile air flight, entry motion and water entry. Photographic coverage of the VAL range was normally provided by eight separate cameras which could be selected and prepared prior to launching. These cameras are described below. (See Figures #10 and 11).

The general side view cameras (GSV) were fixed position cameras located at stations 1100, 1400, and 1700 along the west bank of the reservoir. These cameras could be selected as necessary to record a general view of the projectile water entry point. Used in conjunction with one another and with other cameras, their film records provided data which could be used to establish an average true attitude angle and an average trajectory angle for the projectile.

The side view cameras, (SVM) and (SVP) which were located on a moveable camera car on the west shore of the reservoir, provided data for calibration of distance measurements, timing pulse, projectile distance measurement and a more accurate measurement of projectile water entry angle and trajectory angle. These were used in conjunction with a spar buoy positioned so that its outboard end was located 26 feet within the estimated water entry point. The spar buoy provided a physical reference point for water entry calculations.

Used in conjunction with side view records, the rear view camera (RV) provided film footage for measuring torpedo attitude angle. The overhead camera (OH) recorded the water entry point dynamics and a general view of the launch was provided by the general rear view camera (GRV).

When the VAL range was built, the hydrophone range was a primary means of monitoring the underwater behavior of projectiles. The hydrophone range consisted of 24 hydrophones positioned in 12 pairs to form an enclosure which was 750 feet long, 150 feet wide and 75 feet deep. The hydrophones were held in position by buoys and anchor lines and were positioned in paired groups which formed five linked 150 x 75 foot bays. The upper hydrophones of each pair were 15 feet below the surface of the reservoir and the lower were located 90 feet below the surface (see Figure #23).

The hydrophone range was in position and available for monitoring underwater projectile performance up to the 1990's. However, the speed of modern underwater projectiles had surpassed its usefulness. The hydrophone range was designed to record the sound of exploding blasting caps which were set to detonate as the projectile passed through the hydrophone array. Since the projectile passage time was quick, the caps needed to be detonated in extremely short intervals. The shortened interval between cap detonates caused overlap interference which was worsened by scattered acoustic feedback caused by the reservoir bottom configuration and proximity. Therefore, as the speed increased with the new torpedoes, the usefulness of the hydrophone range decreased.

Due to the high noise level in the early part of the underwater trajectory, caused by cavity collapse, turbulence, pieces of the sabot striking the water and reflected noise from the launching, hydrophones could not produce valid data during the water entry or "open-cavity" phase. Magnetic loops were sometimes employed to supplement the hydrophone range during the "open-cavity" stage. A magnetic loop gave the time at which a projectile passed through it but could not define its position or orientation. Each loop was 25 feet square and consisted of 80 turns of copper wire. The projectile was magnetized or a magnet was installed inside the projectile. The passage of a magnetized projectile through the loop produced a pulse of current which operated the galvanometer of a high speed oscilloscope. This data could provide information for obtaining velocity and acceleration immediately after water entry.

Trajectory nets also supplemented the hydrophone range during the "open-cavity" stage. Underwater nets, made of netting twine, provided data on the path followed by the projectile. The nets were suspended vertically at intervals beginning just beyond the entry point. Breakage of strands, which were easily broken and did not appreciably impede the travel or alter the projectile's behavior, indicated the projectile's position as it passed through the plane of each net. After each launching, the nets were withdrawn, spread out on a level area, and the coordinates of the holes were recorded. Several sizes of nets and appropriate mesh sizes were available for various projectile launchings.

Underwater photography was attempted by suspending motion-picture cameras in water tight containers near the entry point. However, satisfactory pictures could only be obtained under the most favorable conditions of light and water clarity. Water clarified by various methods was introduced at the entry point but further research was needed for this method to become effective. It is important to remember that this was an experimental facility and new ideas were being regularly tested there. This included recording methods as well as the projectiles being launched.

After a successful launch, a recovery crew would go out to retrieve the projectile. Most projectiles would be floating in the reservoir. A line was attached and the projectile was pulled back to the dock for transfer back to the torpedo shop. However, sometimes a projectile would sink. A bubbler on the projectile allowed the recovery crew to spot its location. A diving crew would descend to find the projectile by following the bubble trail. A fire pump and hose was used to pump water and blow away the soft silt on the bottom of the reservoir in order for the divers to find the projectile. A line would be attached and the projectile would be hoisted up to the dive barge.

Data from all the recording stations would be collected, processed and reviewed with the help and coordination of many people. From the final analysis, determinations were made for changes, or modifications to be tried on future launches.

Prior to the loading of a projectile onto the VAL, the angle of the launch was determined and the launcher positioned to the correct angle. This procedure is outlined in the 23 steps of Table 3-5, VAL Main Hoist and Windstay Operating Procedures (NOSC:33-31 through 3-34). A 75 horse power motor ran the main drive to move the cables between the counterweight car and the bridge support carriage. The three drum drive of the main drive machinery, each with an 84 inch pitch, allows a 270 degree wrap angle on the driving drum. Coupled with a triple-reduction speed reducer, this creates a motor to drum ratio of 966 to 1 and gives a maximum running speed of approximately 20 feet per minute.

Controls for the main drive and windstay winches are located together in the "crows nest" at the top of the concrete "A" frame structure of the VAL. A portable control panel could also be used from the bridge support carriage. Moving the launching bridge to a new angle required the operation of the main drive and the windstay winches simultaneously. First, the locking pins were removed to allow movement of the carriage. Windstay wench brakes were then released allowing movement of the launcher. Because the launching bridge structure weighs more than the counterweight car, minimal power was needed to lower the launcher. When the launcher bridge had reached the correct angle, the windstay winch brakes were set followed by the replacing of the locking pins tor the carriage. A final alignment was made using the windstay winches to align the launcher with the firing range.

Some test shots would require a land backdrop to provide tor a potential ricochet. In these cases, the windstay winches would pivot the launcher bridge off center from the normal firing range. This allowed for a safe launching even it the projectile skipped or ricocheted off the water.

Propulsion tor the launching was provided by compressed air. A 500 cubic toot flask supplied compressed air up to a maximum of 1,000 pounds per square inch tor launchings. Table 3-2 shows the VAL Main and Auxiliary Air Tank Pressurization Procedures (NOSC:3-20 through 3-23). Two ditterent compressors could be used to supply the compressed air.

The air was released into the launching tube through a "Y" joint from the pressurized tlask. No available valve could release the air trom the flask into the launching tube as quickly as required for the launch. So, the engineers designed and built their own valve called the Quick Acting Valve (QAV). The QAV used a piston to open and release the pressurized air in 1/10 of a second. (See Figure #19 &20) The launching sounded like a large canon with a loud "Ba-Boom" that would echo ott the canyon walls.

Many ditterent projectiles were launched through the VAL over the years in addition to torpedoes. The uniqueness of the VAL brought a variety of full scale projectiles to be tested at high velocities into the reservoir. Lite boats rolled up into sausage shapes were tested for high altitude drops from planes. The "Black Box", now used on all commercial jet airliners, was tested during its development at the VAL. Other types of missiles were also shot through the VAL during testing and development including the Tomahawk Cruise Missile. Over many years and thousands ot launchings, the Variable-Angle Launcher performed flawlessly due in part to thorough operating procedures and maintenance tollowed routinely by the personnel involved.

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Figure 15. Launching Bridge Elevations with Controlling Dimensions (United States Navy, NAVORD Report 1327).

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Figure 24. Variable-Angle Launcher Hydrophone Layout. (Naval Ocean Systems Center, Variable-Angle Launcher Naval Ocean Systems Center Morris Dam Operating Procedures and Maintenance).

Figure 25. Morris Dam Test Facility Aerial Perspective Showing Fixed-Angle Launching Range as of July 1945. (KEA Environmental, Inc., Historic and Archaeologic Resources Protection Plan for Morris Dam Test Facility, Azuza).

Figure 26. Fixed Angle Launcher Plan and Sectional Elevation. (KEA Environmental, Inc., Historic and Archaeologic Resources Protection Plan for Morris Dam Test Facility, Azuza).

Figure 27. Plan of Torpedo Shop Circa 1993. (KEA Environmental, Inc., Historic and Archaeologic Resources Protection Plan for Morris Dam Test Facility, Azuza).

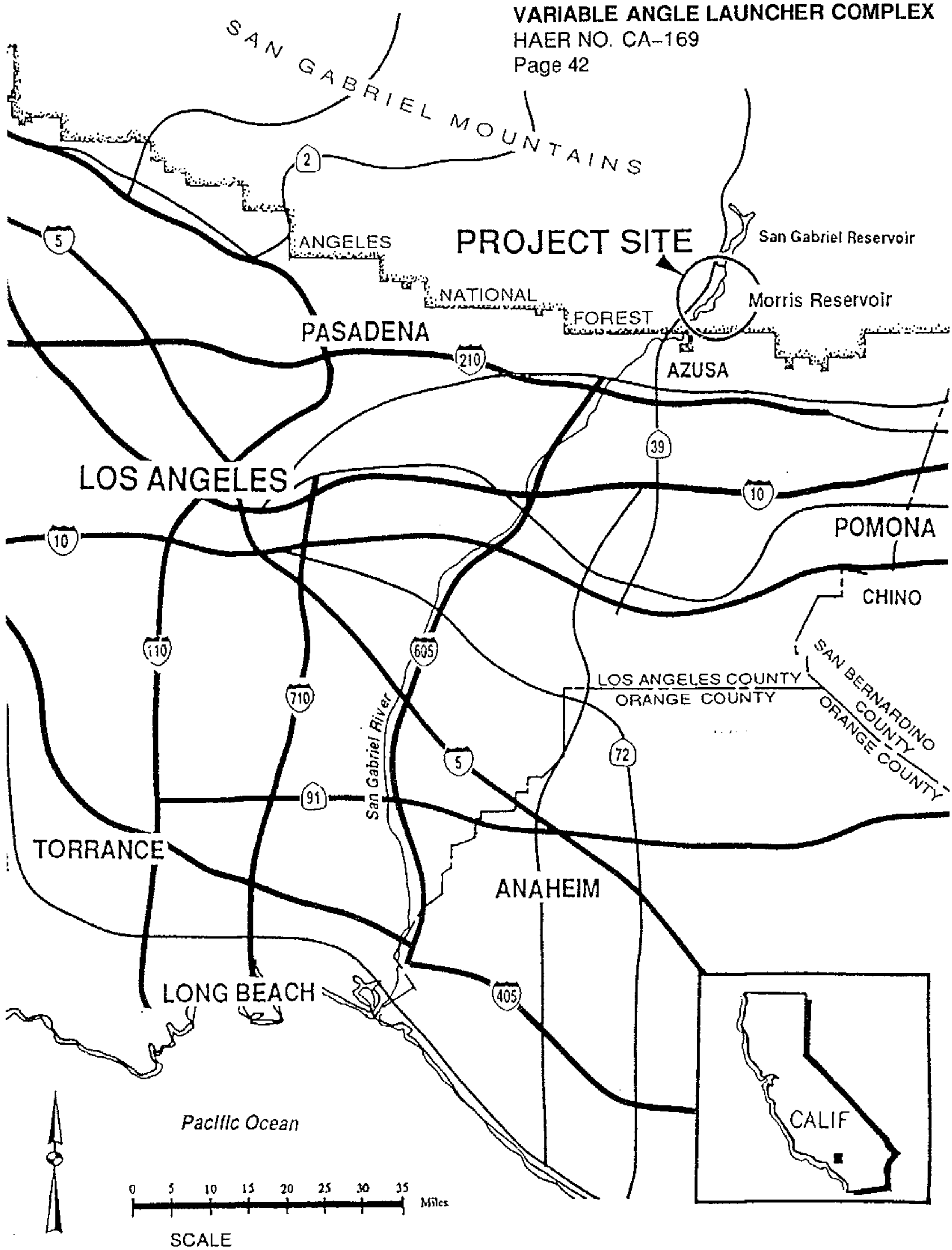


FIGURE 1. Project Vicinity Map.

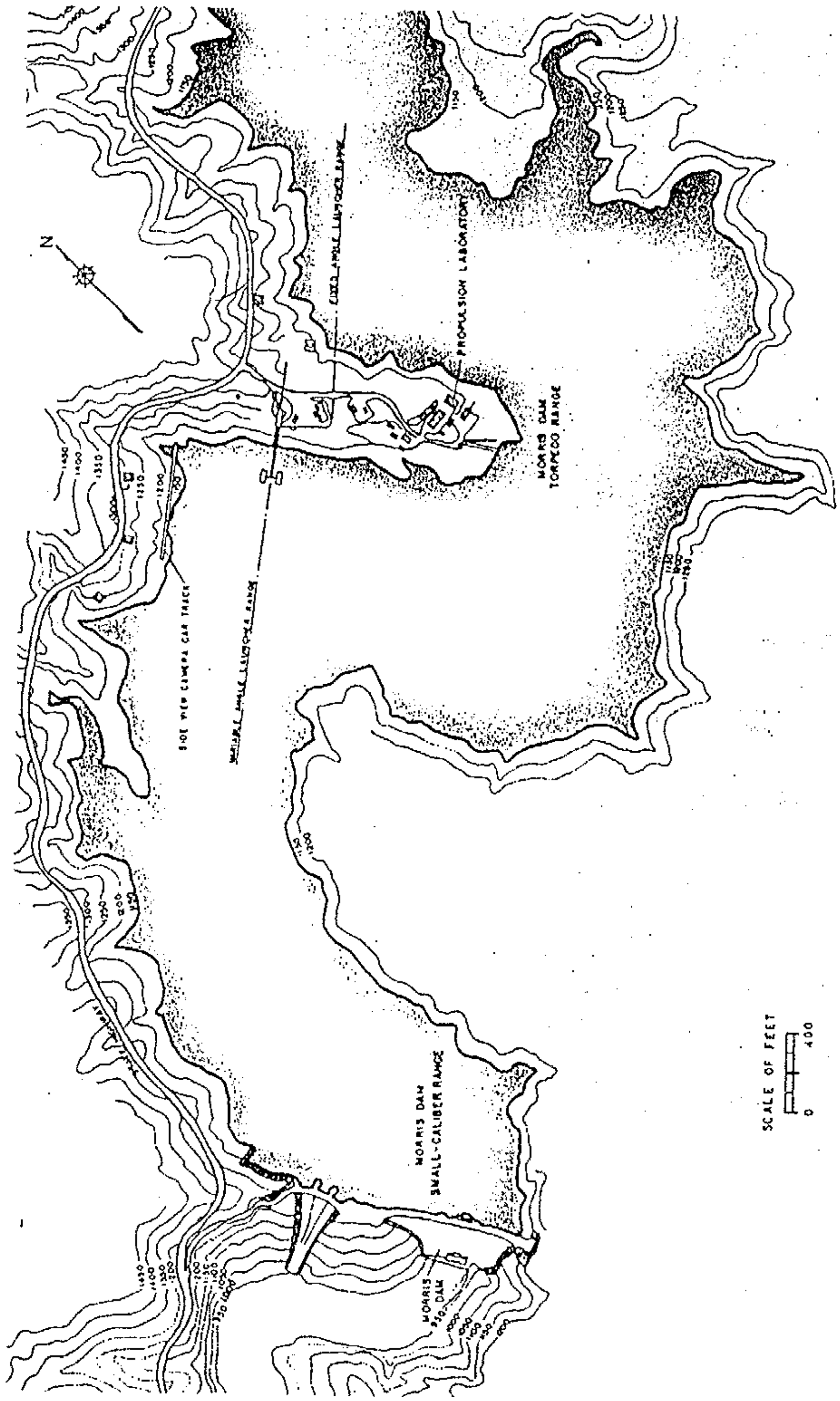


FIGURE 2. Site Map of Morris Dam Test Facilities. Circa 1950.

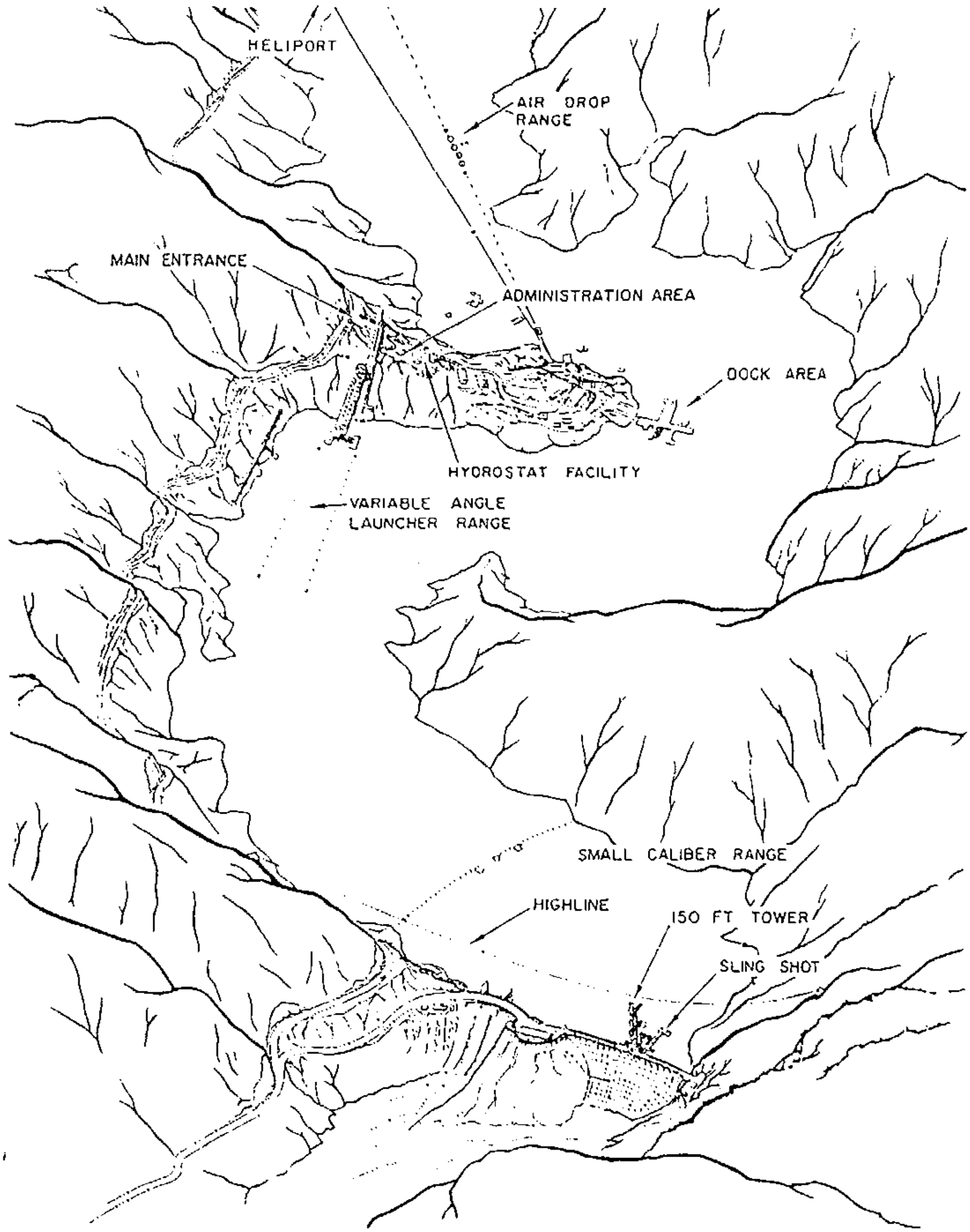


FIGURE 3. Site Map of Morris Dam Test Facilities Circa 1970's.

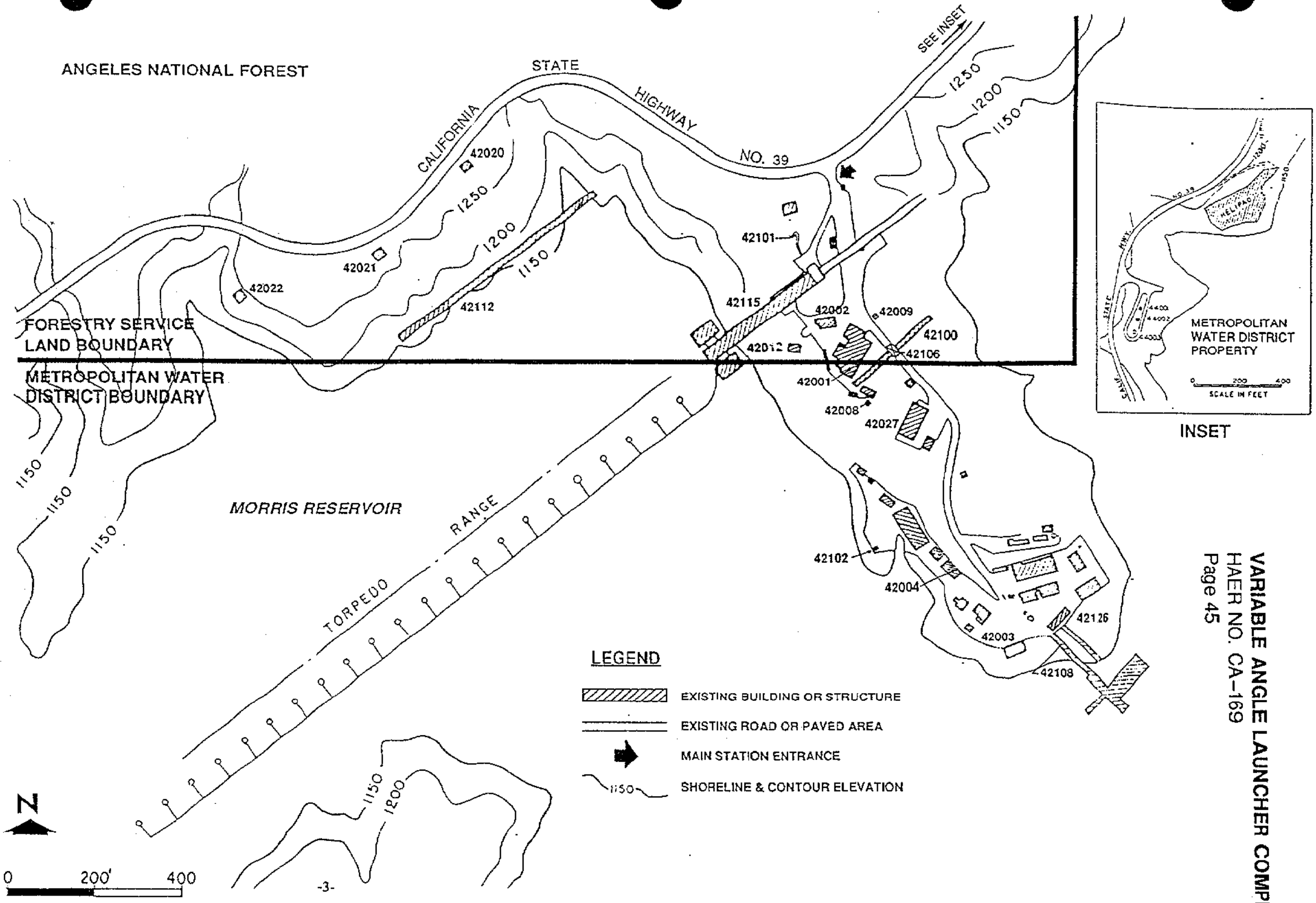


FIGURE 4. Site Plan of Morris Dam Test Facilities. Circa 1990's.

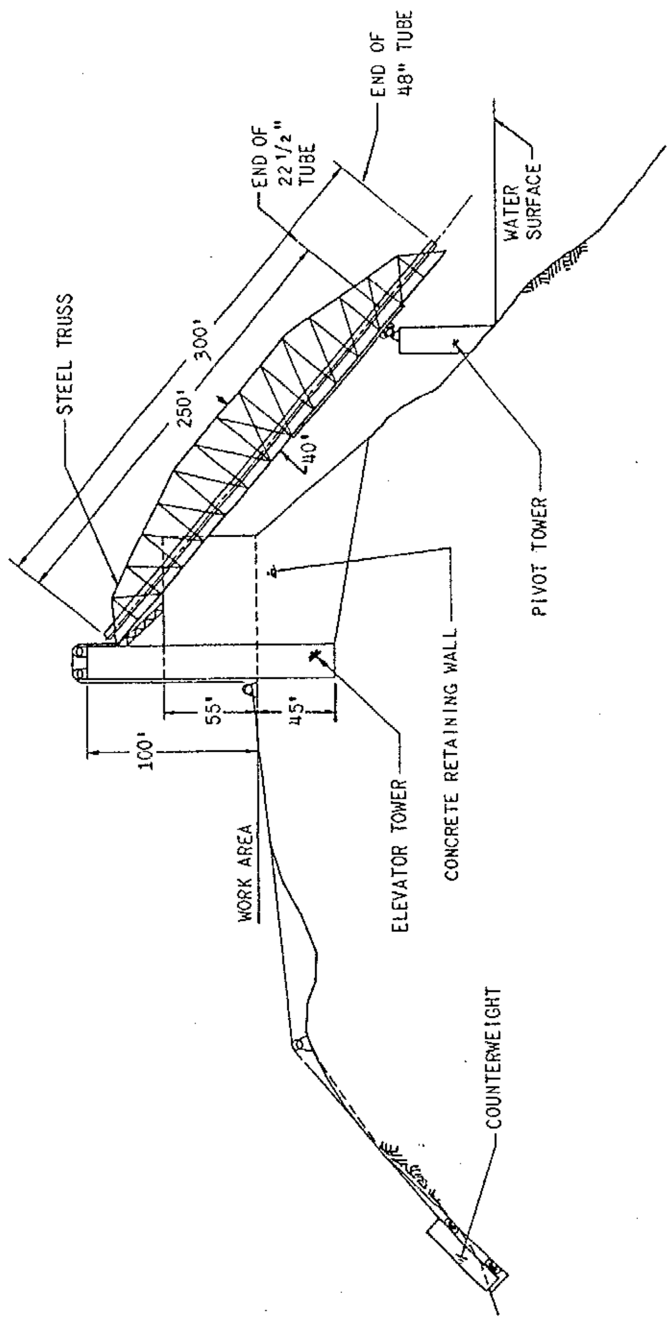


FIGURE 5. Tower–System Launcher Design Scheme.

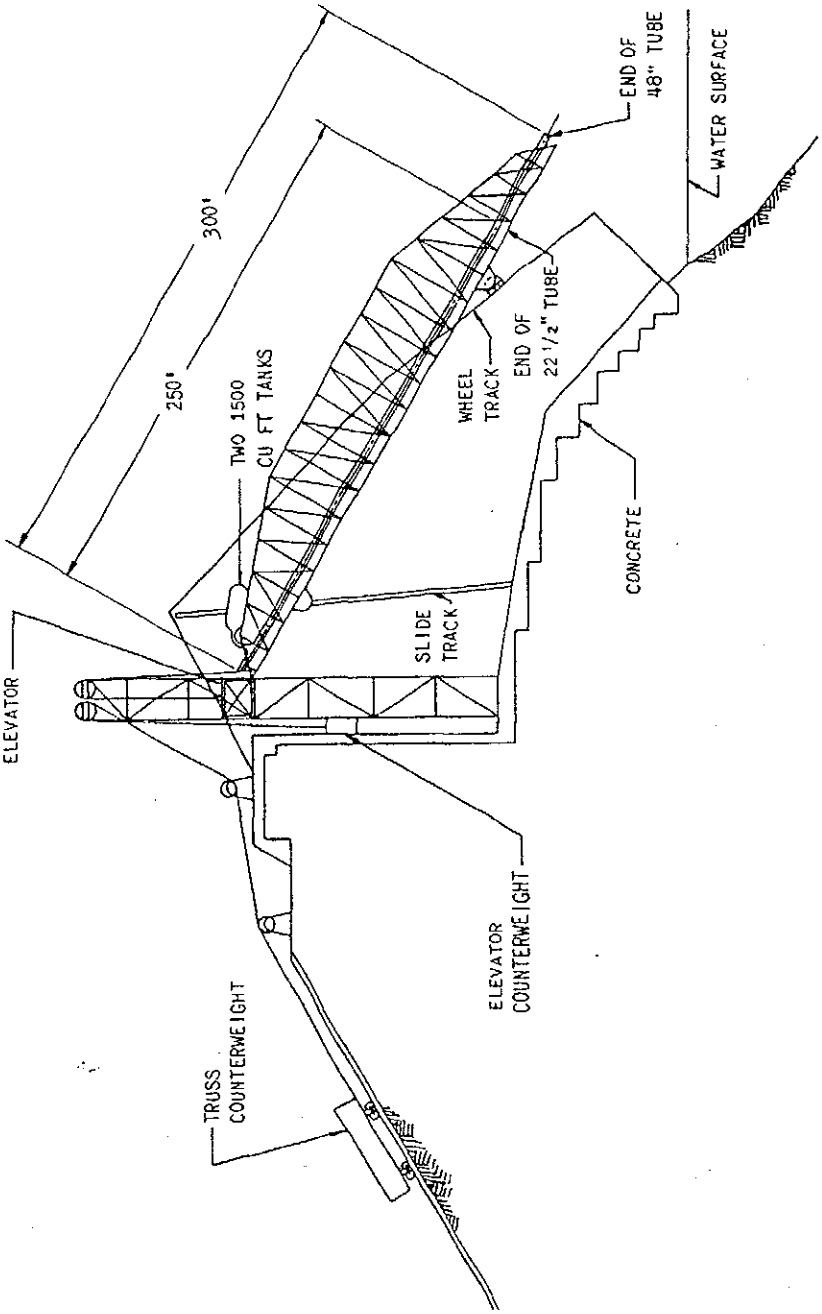


FIGURE 6. Dual-Rail Launcher Design Scheme.

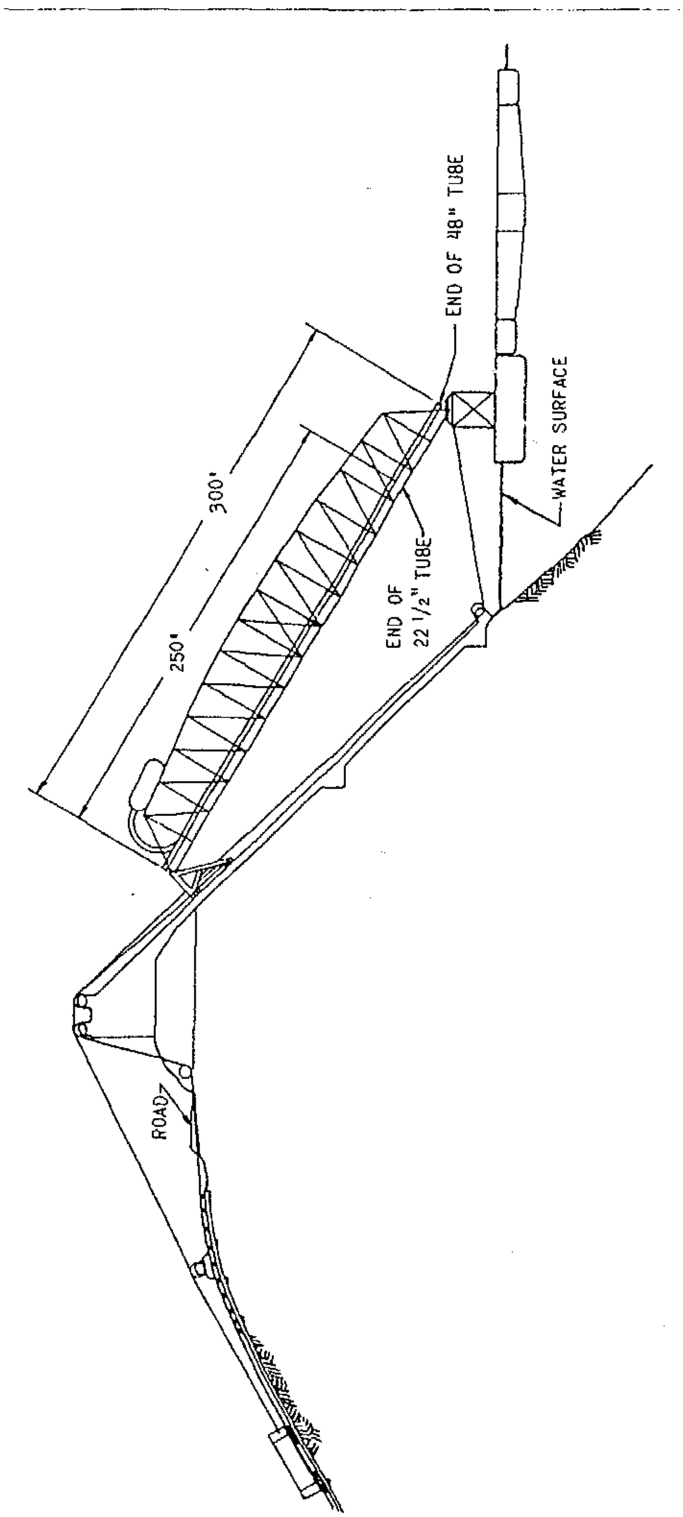


FIGURE 7. Barge Type Launcher Design Scheme.

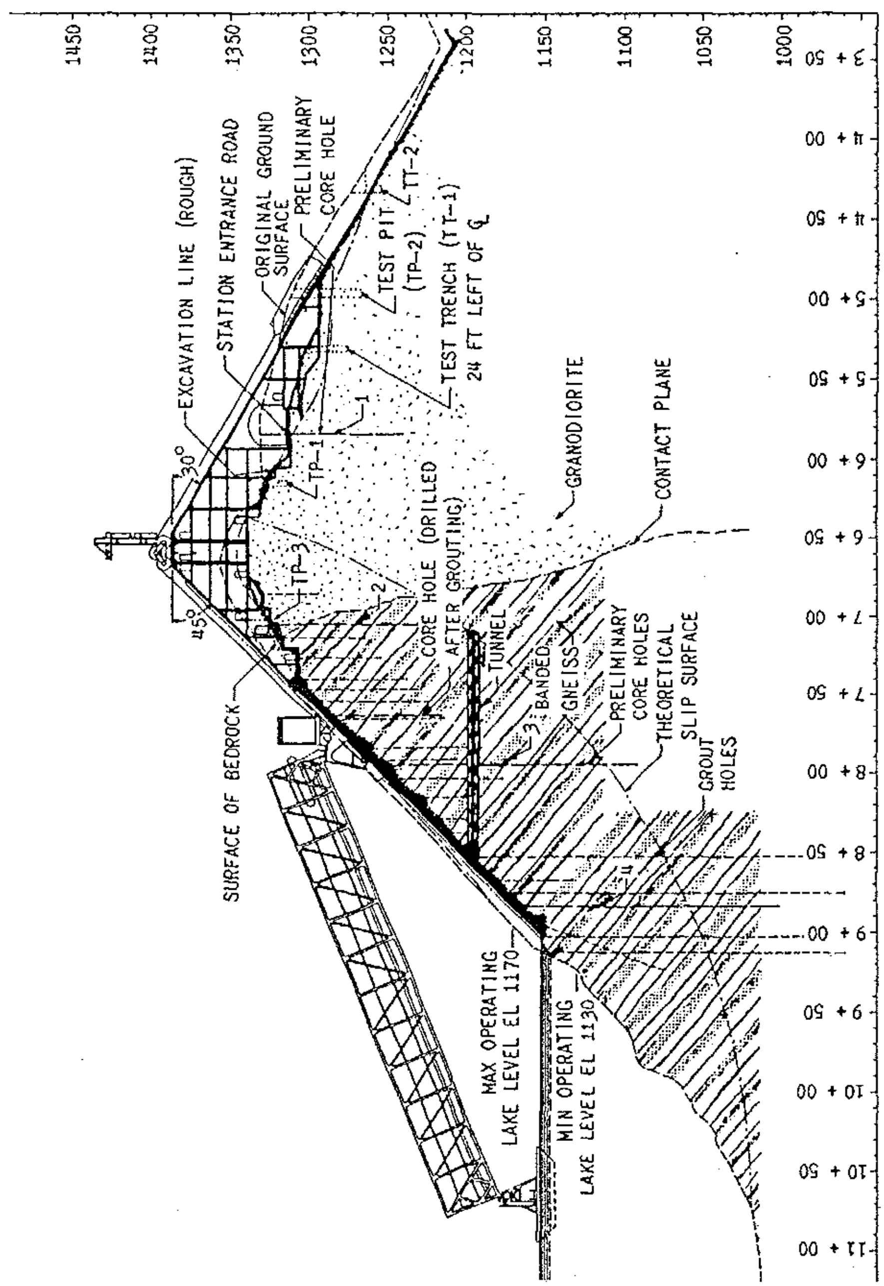


FIGURE 8. Longitudinal Section on Centerline of the Launcher Showing Geological Structure Foundation.

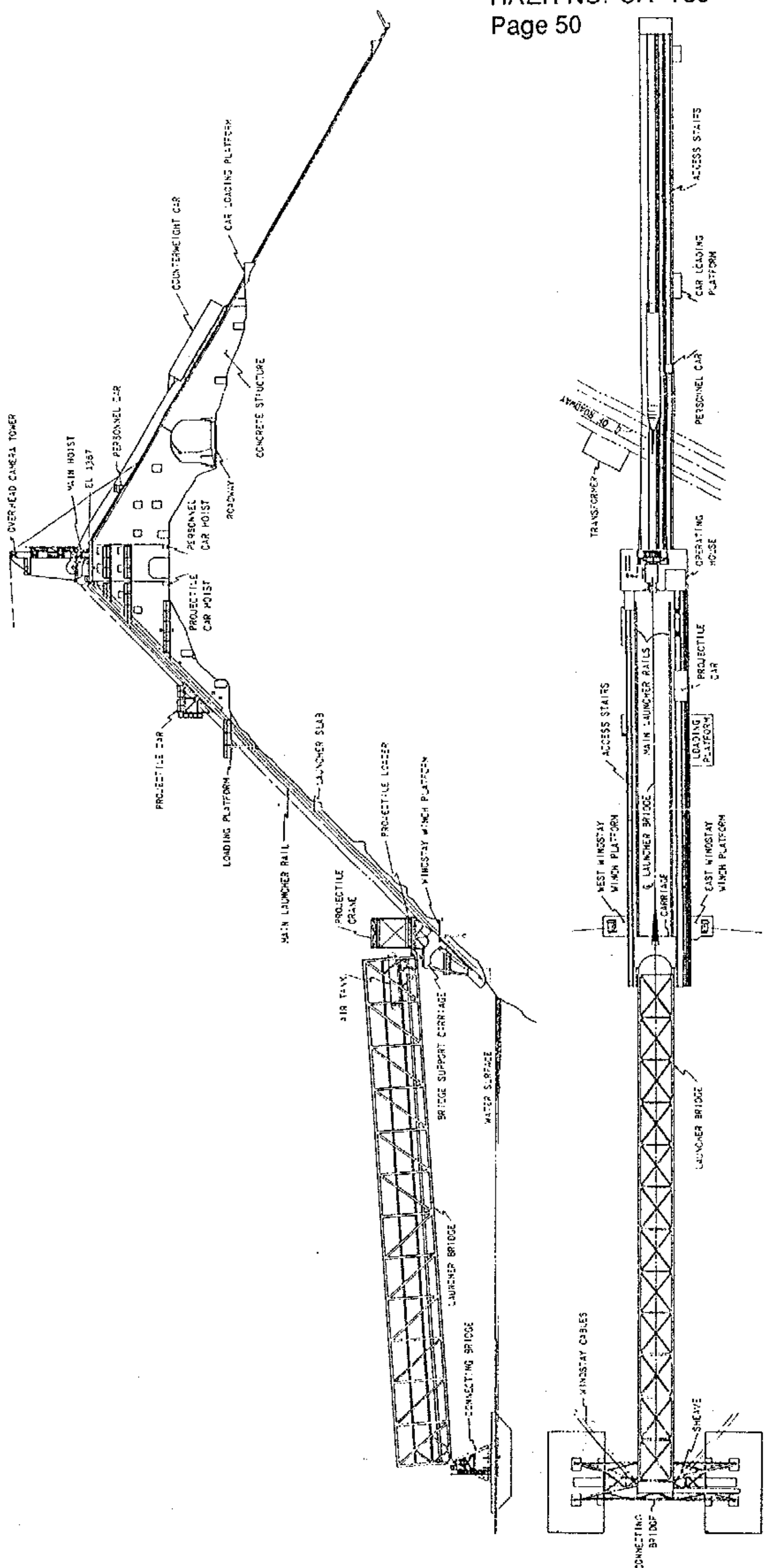


FIGURE 9. Variable-Angle Launcher Plan and Elevation.

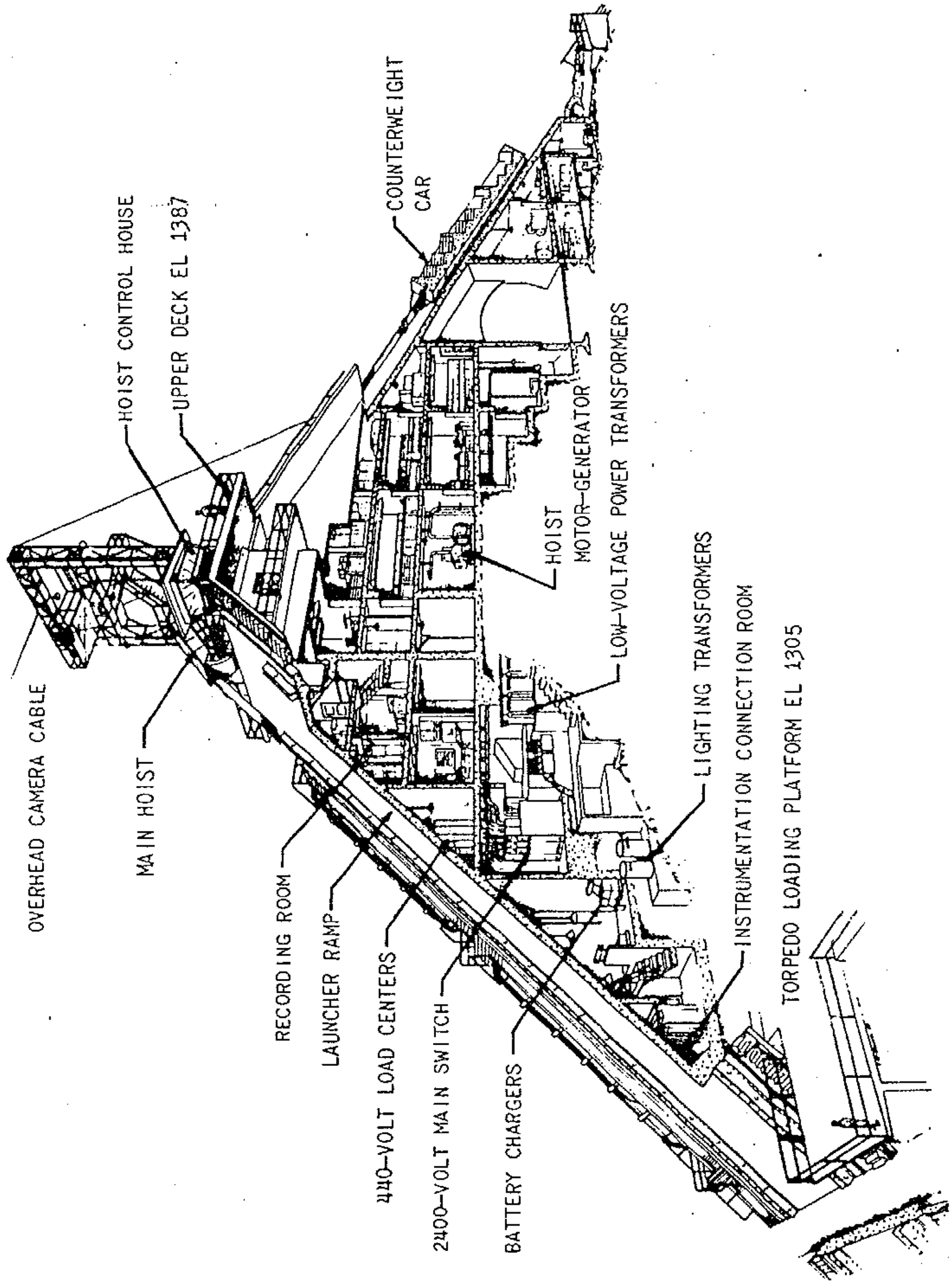


FIGURE 10. Cutaway Section of Variable-Angle Launcher Concrete Cellular Structure.

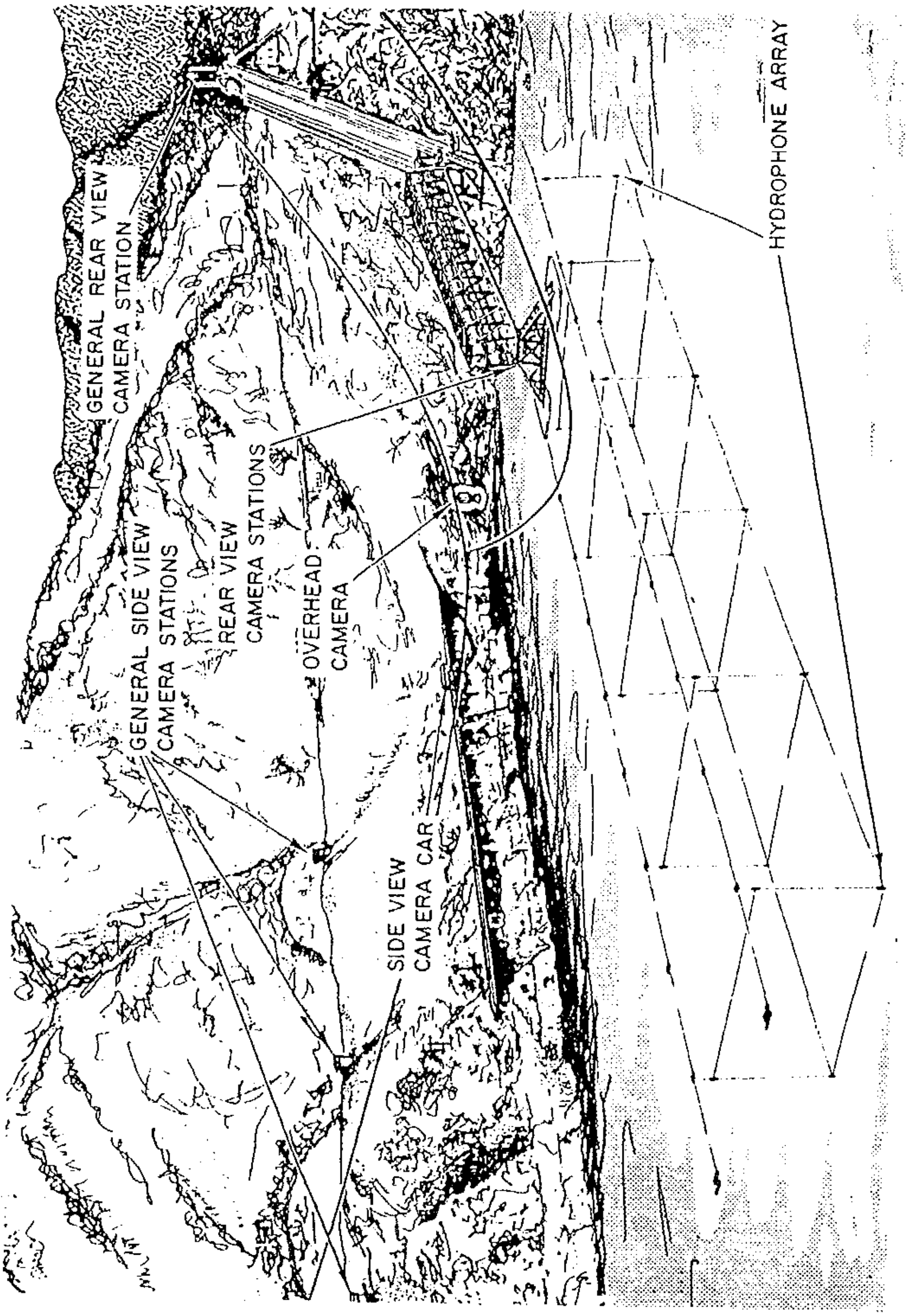


FIGURE 11. Variable-Angle Launcher Firing Range with Recording Devices.

CAMERA NAME	CAMERA SPEED	POSITION	DEPRESSION ANGLE	DISTANCE TO LAUNCHER ℄	FIELD OF VIEW
General Side View 1100 (GSV) 70mm, 4" lens	32 frames/sec.	Station 1100	15°	688.24 feet	340 feet (Station 930 to 1270) (West bank)
General Side View 1400 (GSV) 70mm, 4" lens	32 frames/sec.	Station 1400	15°	646.45 feet	320 feet (Station 1240 to 1560) (West bank)
General Side View 1700 (GSV) 70mm, 4" lens	32 frames/sec.	Station 1700	15°	759.90 feet	320 feet (Station 1530 to 1850) (West bank)
Side View (SVM) 35mm, 6" lens	120 frames/sec.	Moveable Car	2°	458.25	77 feet, travel distance 511 feet Station 960 to 1471 (West bank)
Side View (SVP)	1000-2000 frames/sec.	Moveable Car		458.25	As above on camera car: mounted 7.5 feet north of SVM.
Overhead (OH) 35mm	64 frames/sec.	Cable above torpedo range ℄		Variable	
Rear View (RV) 16mm, 50mm lens	64 frames/sec.	Launcher barge connector bridge 7.46 feet above lake level.	0°		On launcher connecting bridge for rear view of range
General Rear View (GRV) 6.5" lens		Top of slope in superstructure above main hoist, El, 1427.69 Station 663.39		40" west of ℄	Rear view of range

FIGURE 12. Variable–Angle Launcher Range Camera Coverage.

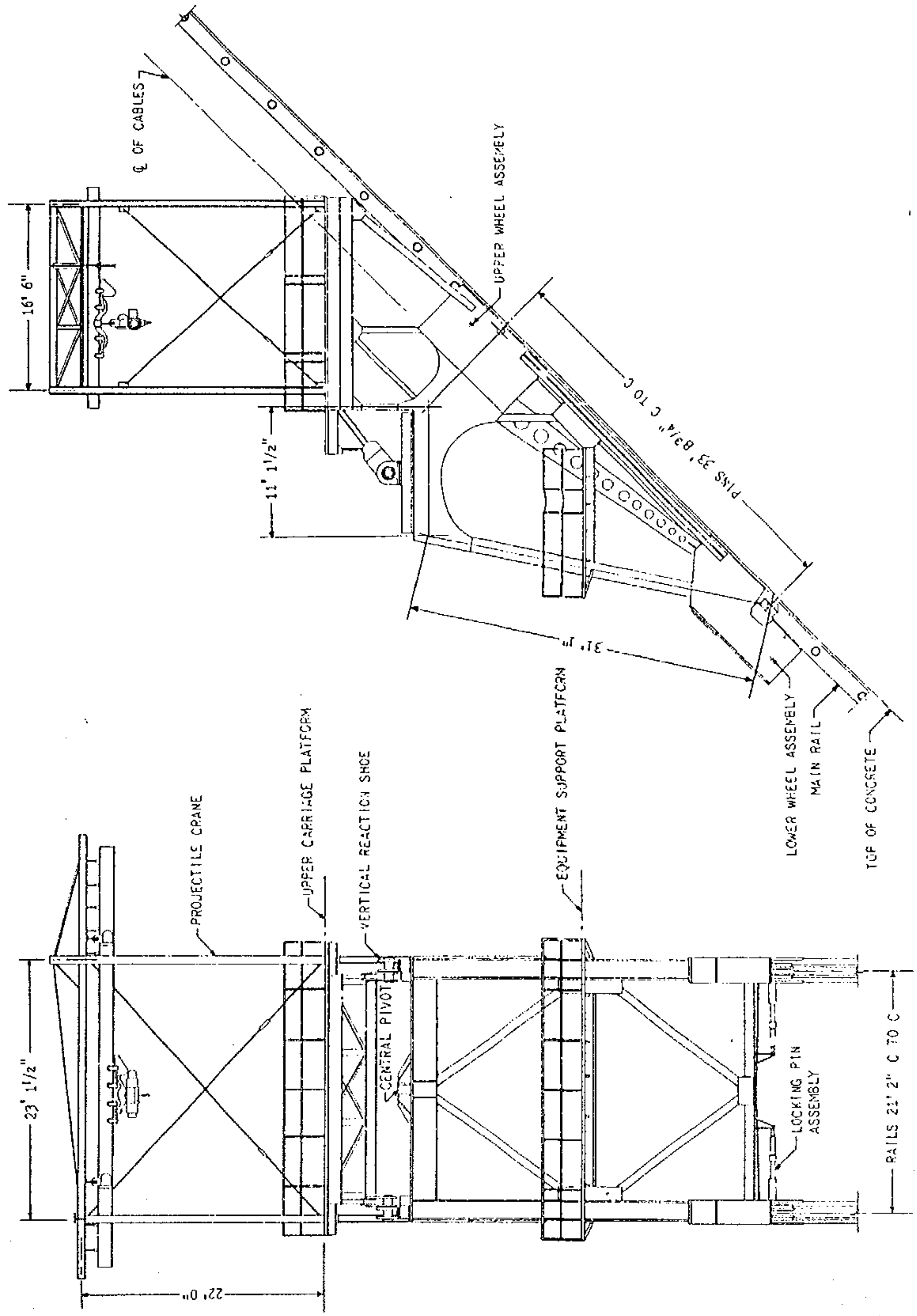


FIGURE 13. Launcher Bridge Support Carriage Elevations with Controlling Dimensions.

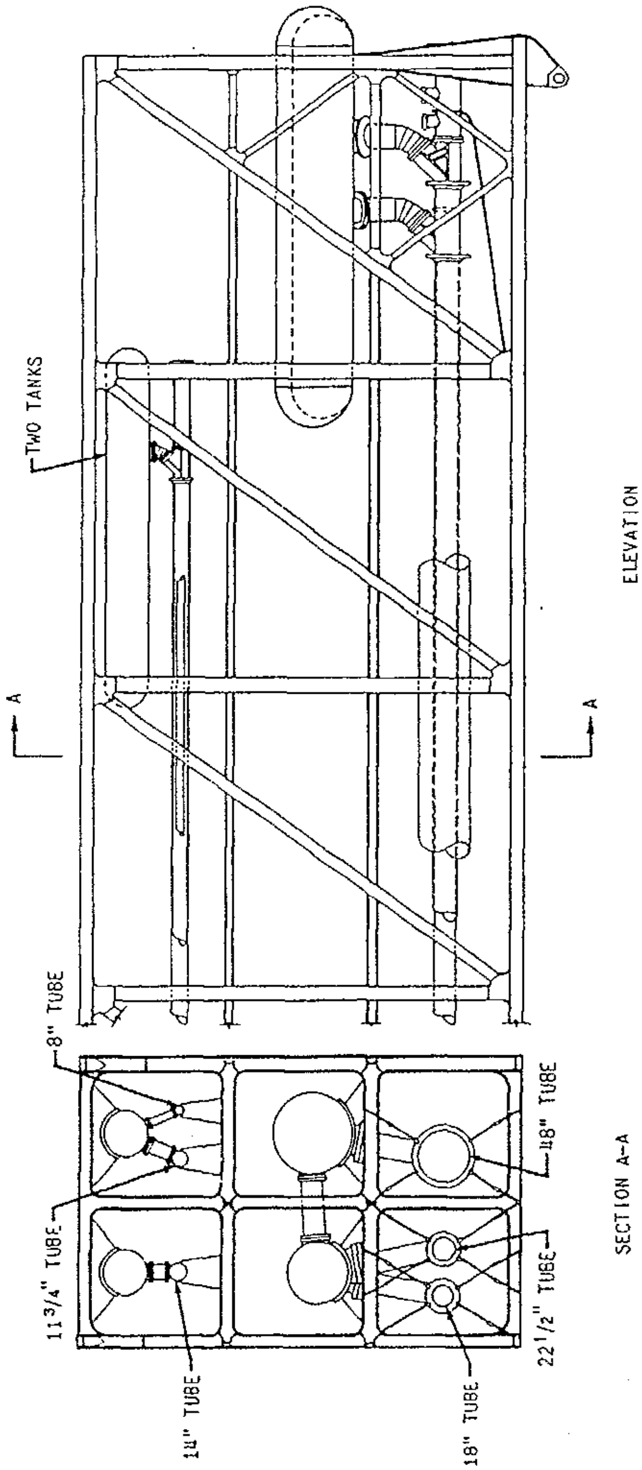


FIGURE 14. Concept Design for Launching Tubes.

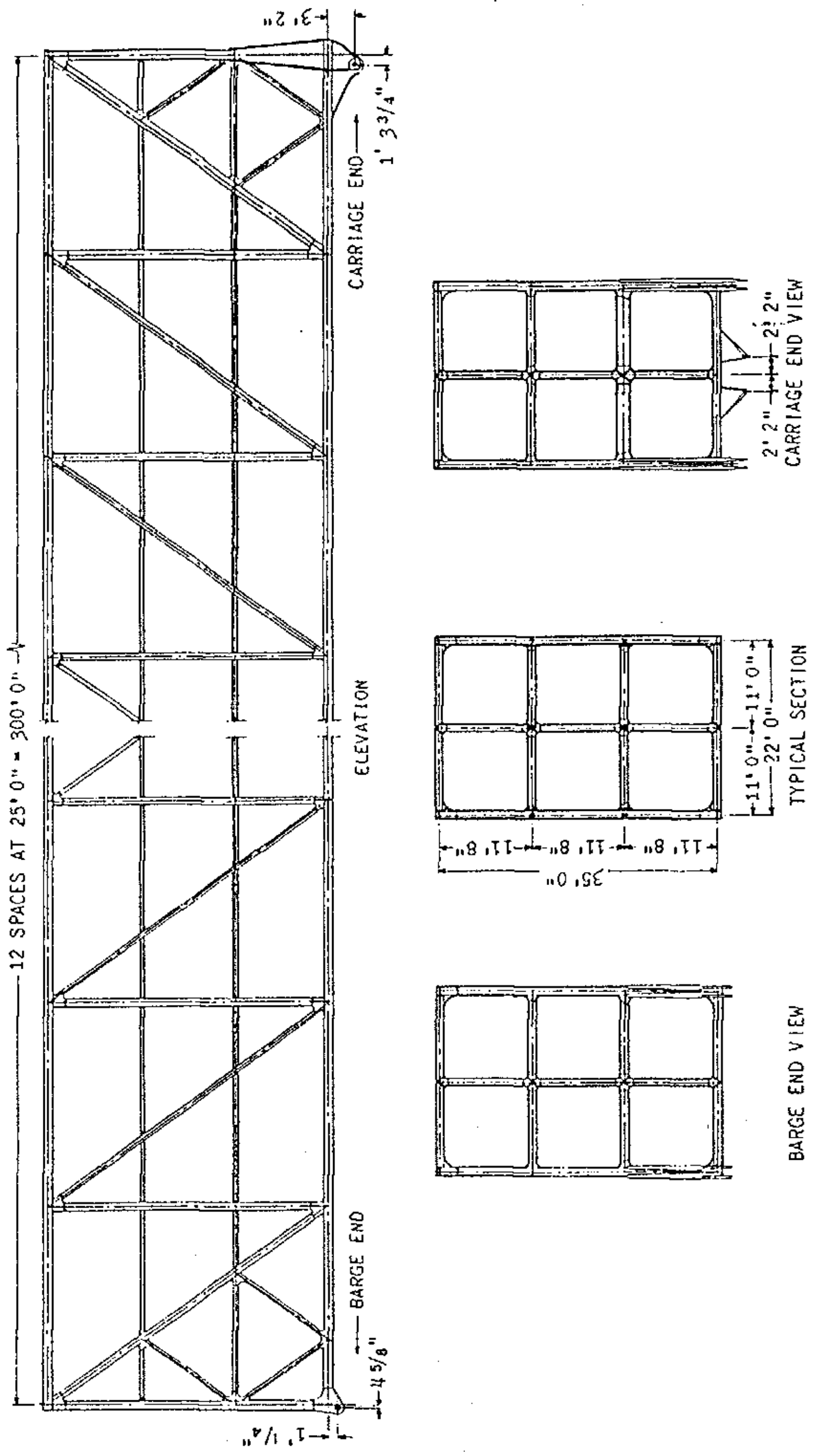


FIGURE 15. Launching Bridge Elevations with Controlling Dimensions.

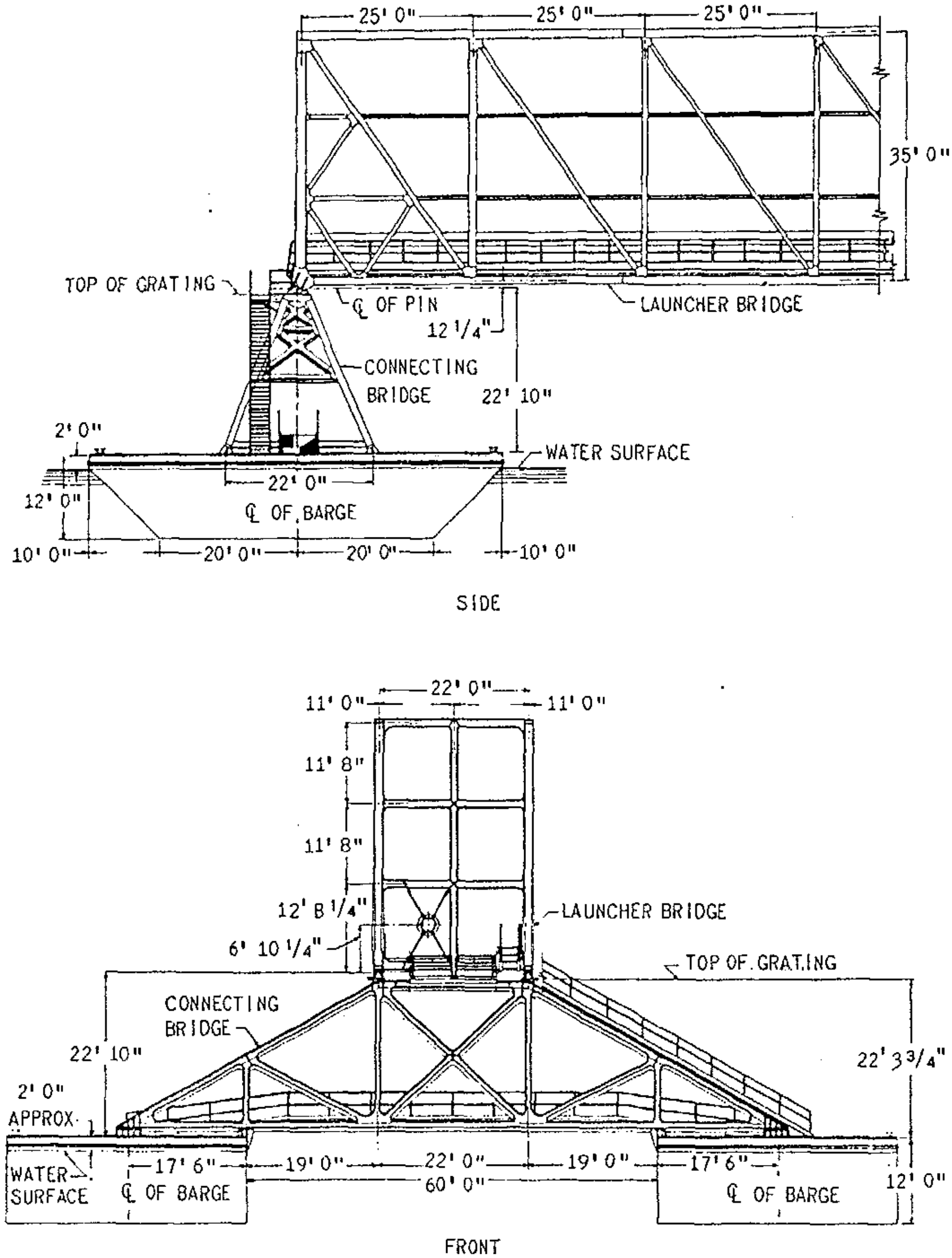


FIGURE 16. Connecting Bridge, Barges and Launcher Bridge Elevations with Controlling Dimensions.

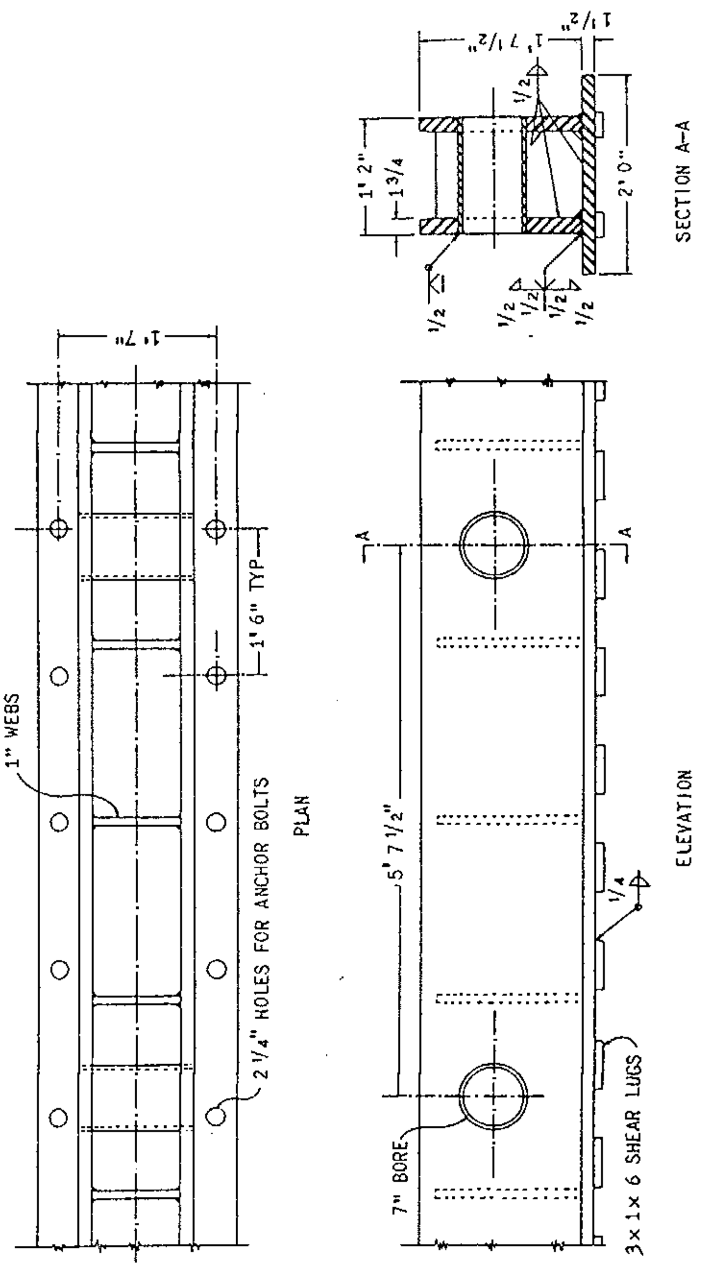


FIGURE 17. Specially Fabricated Rails for Support and Anchorage of Launcher Bridge Carriage.

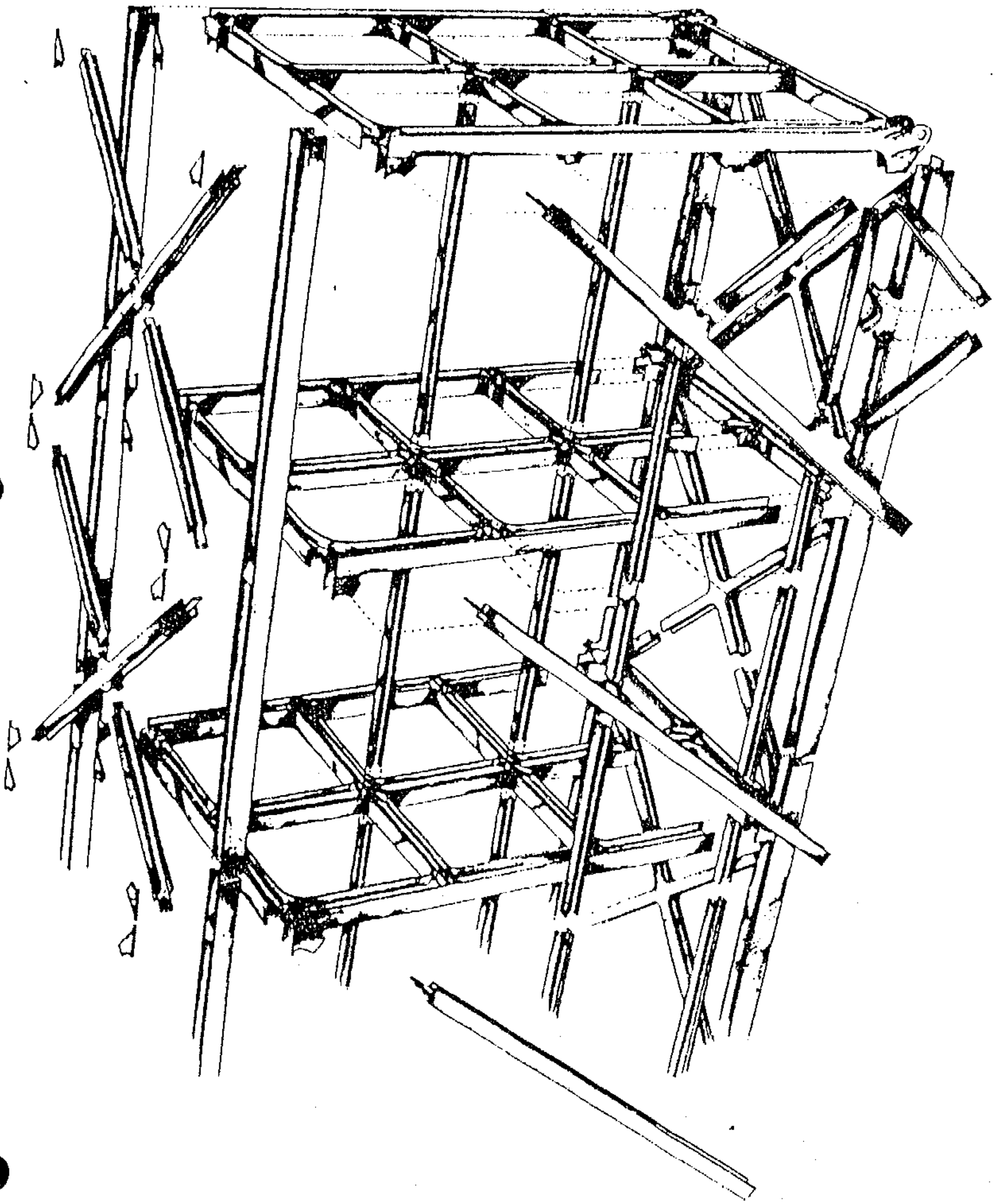


FIGURE 18. Assembly Method for Members of Launcher.

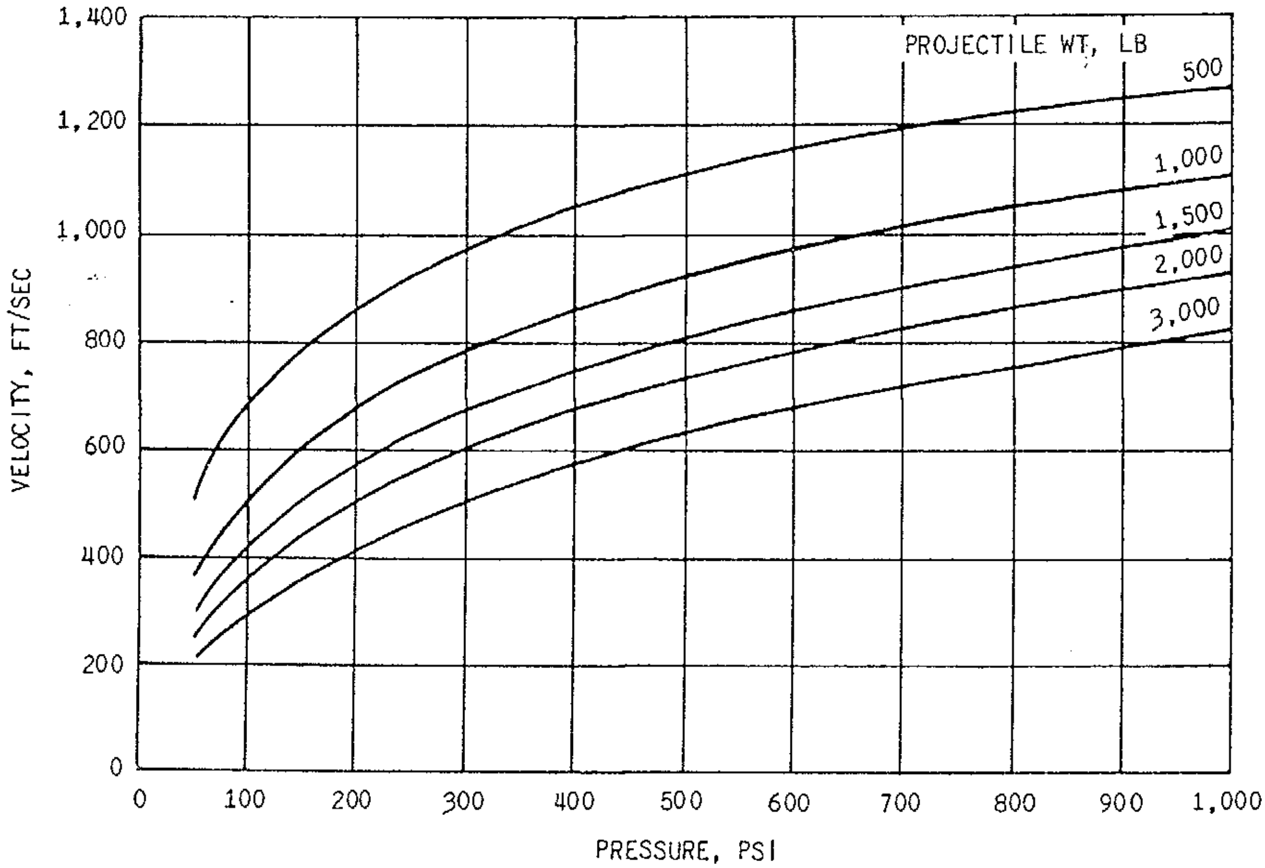


FIGURE 19. Chart Showing Launching Velocities for Various Projectile Weights and Air Pressures.

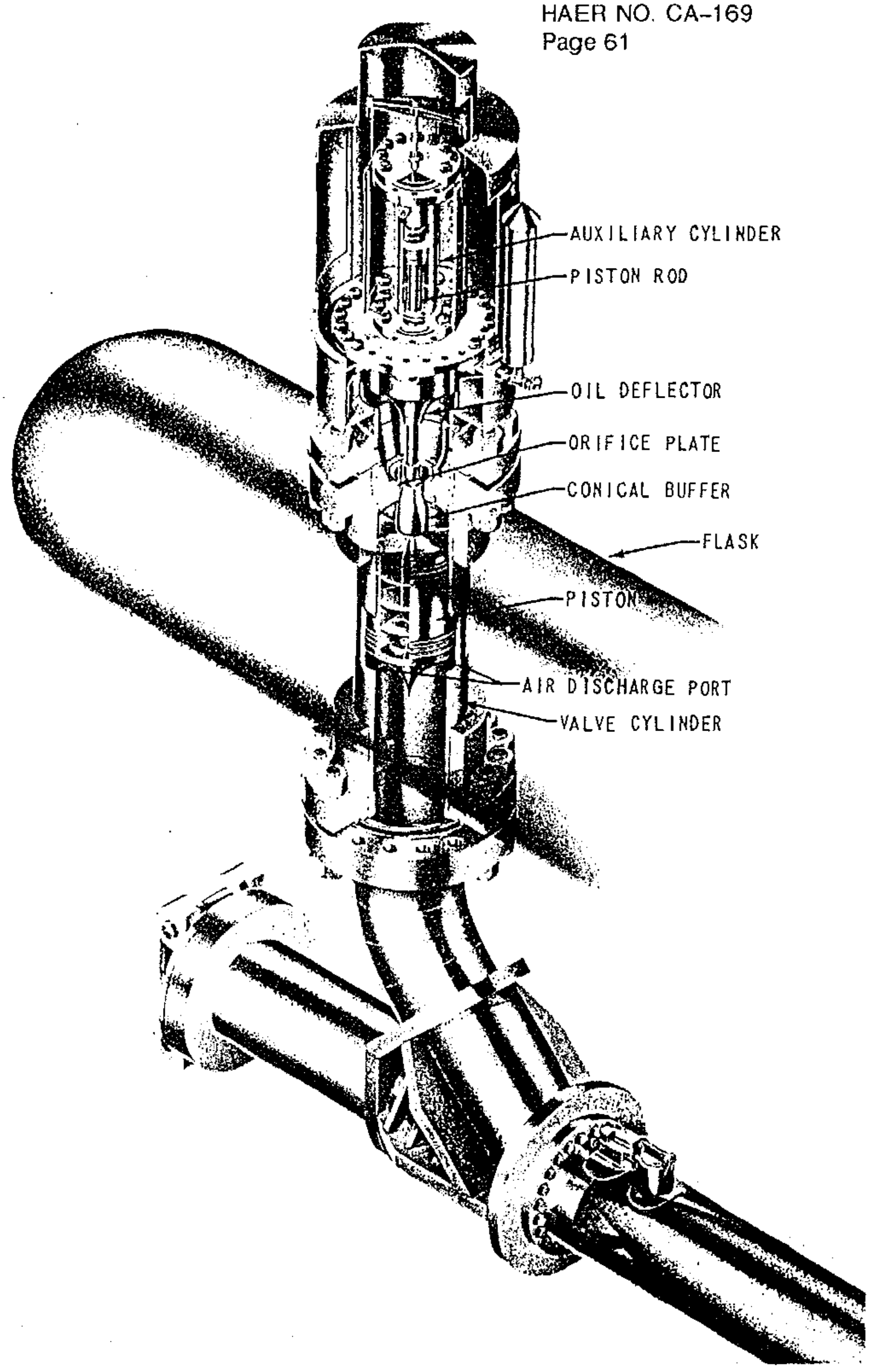


FIGURE 20. Launching Valve (Quick Acting Valve) for the Variable-Angle Launcher.

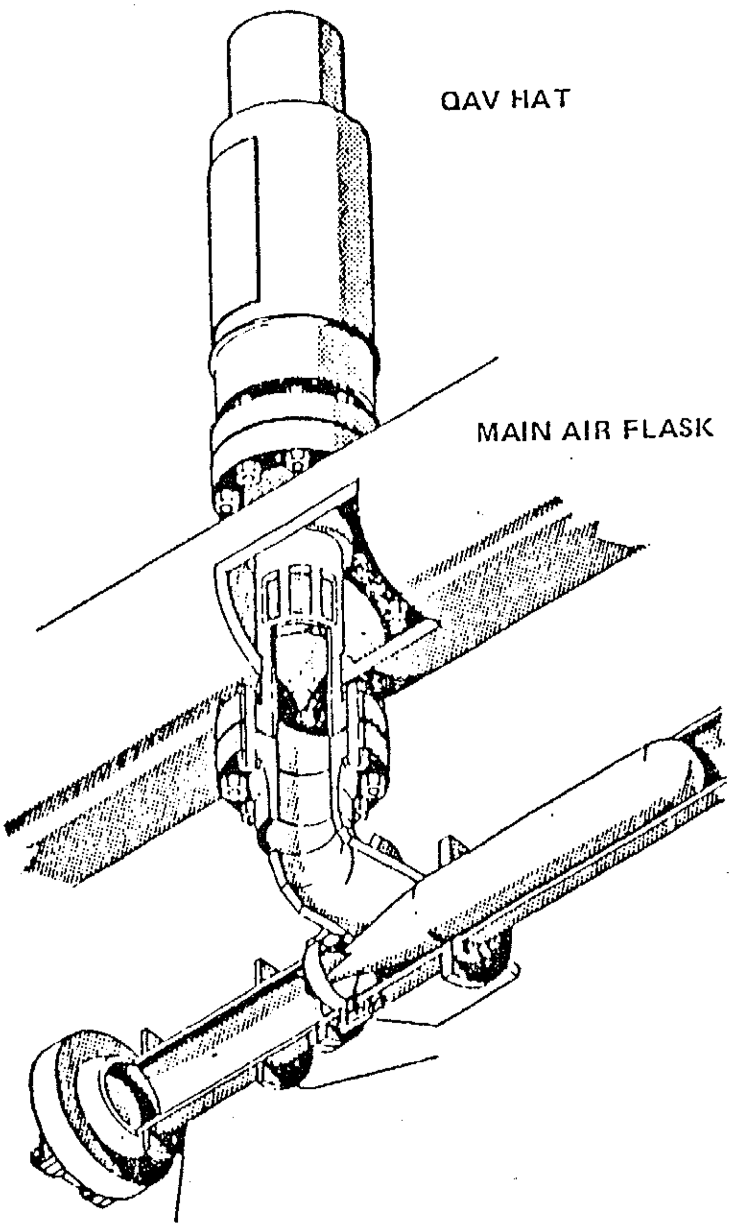


FIGURE 21. Quick Acting Valve and Innerface with Launching Tube.

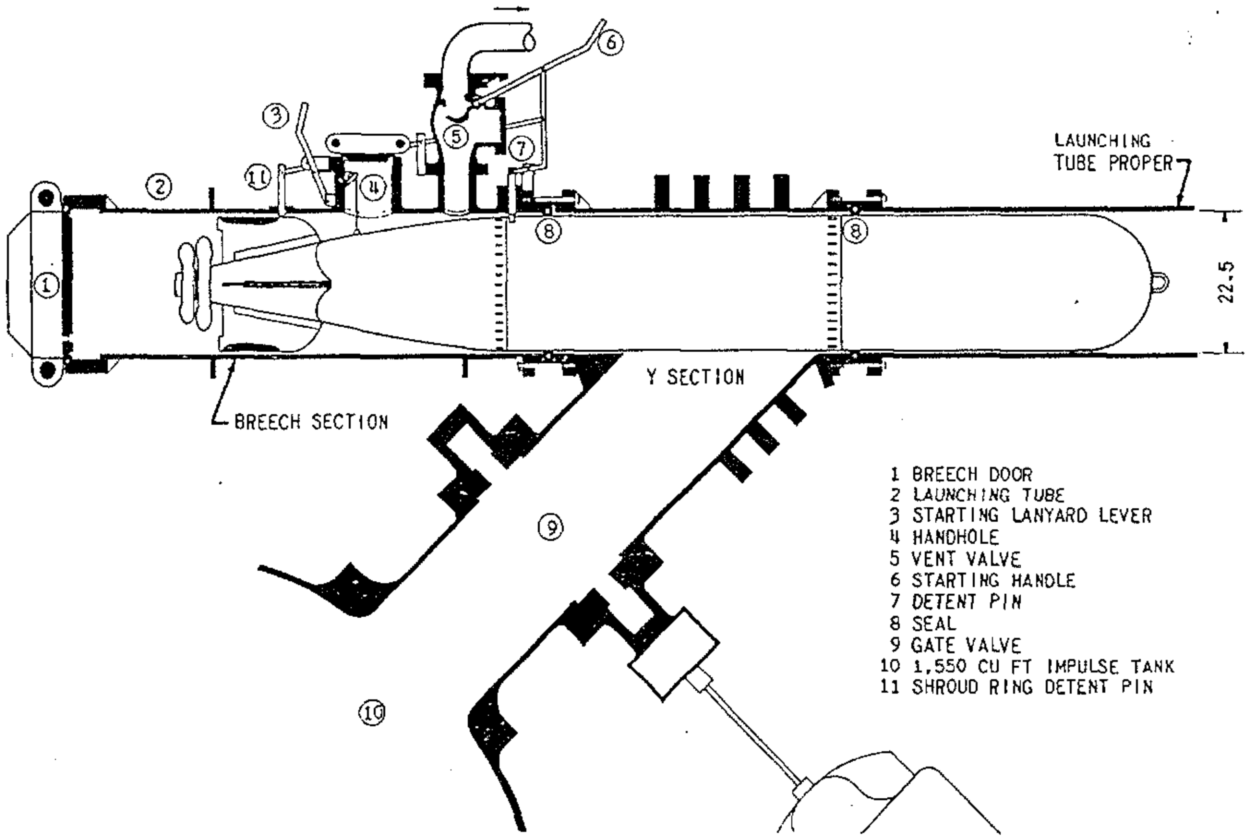


FIGURE 22. Launching Valve of the Fixed-Angle.

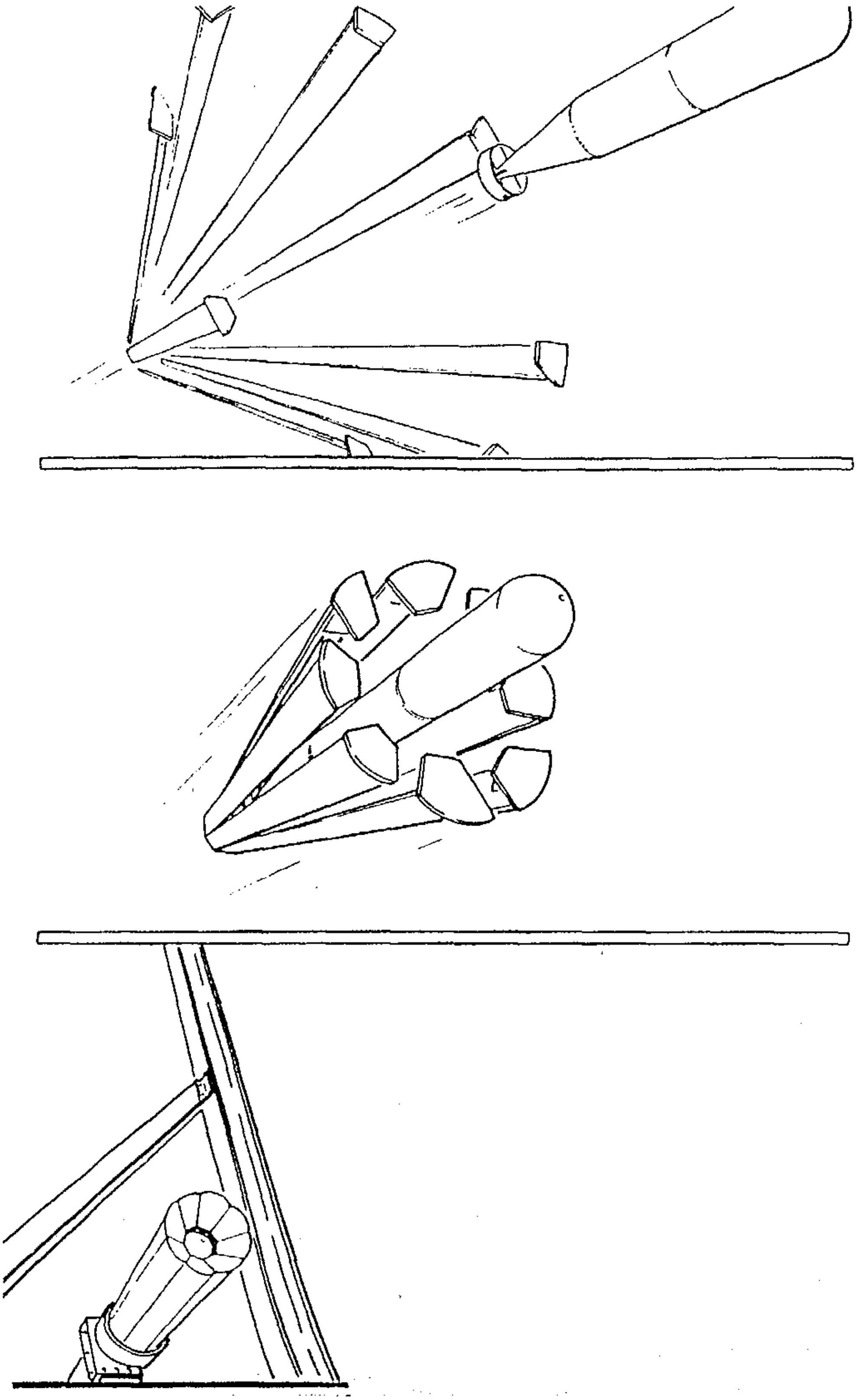
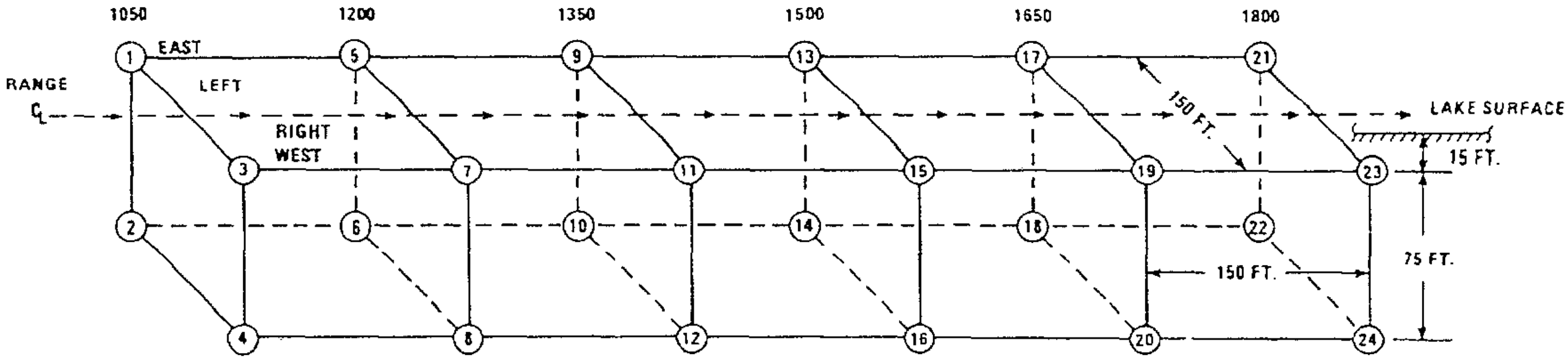


FIGURE 23. Launching a Projectile in a Sabot.



HYD. NO.	AMP. CH.	REC. CH.	HYD. NO.	AMP. CH.	REC. CH.	HYD. NO.	AMP. CH.	REC. CH.
1-13	1	2	5-17	5	6	9-21	9	10
2-14	2	3	6-18	6	7	10-22	10	11
3-15	3	4	7-19	7	8	11-23	11	12
4-16	4	5	8-20	8	9	12-24	12	13

NOTE: ALL HYDROPHONES ARE AT 15 FEET AND 90 FEET RESPECTIVELY EXCEPT 2 AND 4. THE DEPTH OF HYDROPHONES 2 AND 4 IS DEPENDENT UPON LAKE LEVEL (AT LOW LEVELS THEY MUST BE RAISED TO PREVENT THEM FROM RESTING ON THE LAKE BOTTOM).

FIGURE 24. Variable–Angle Launcher Hydrophone Layout.

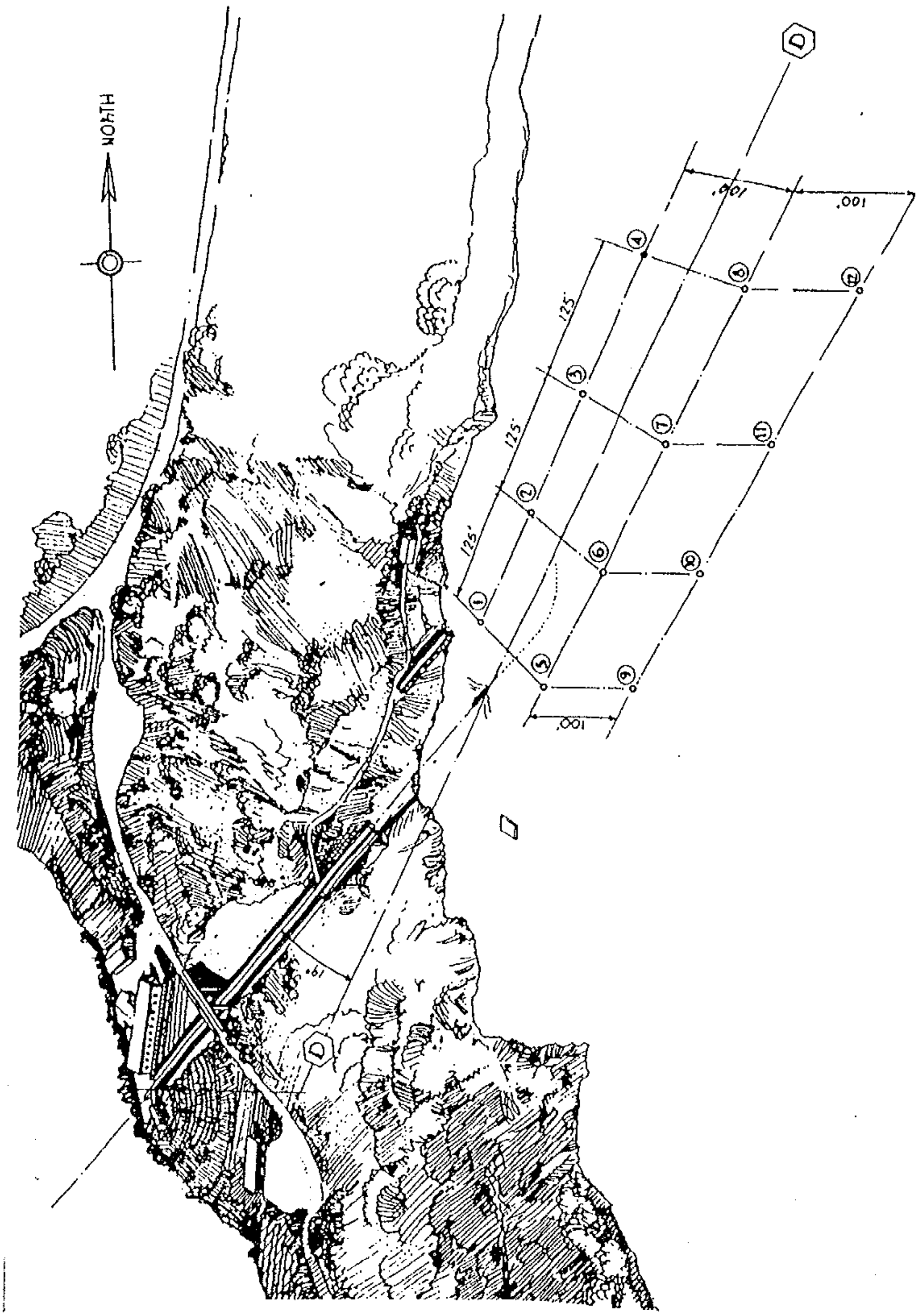


FIGURE 25. Morris Dam Test Facility Aerial Perspective Showing Fixed-Angle Launching Range as of July 1945.

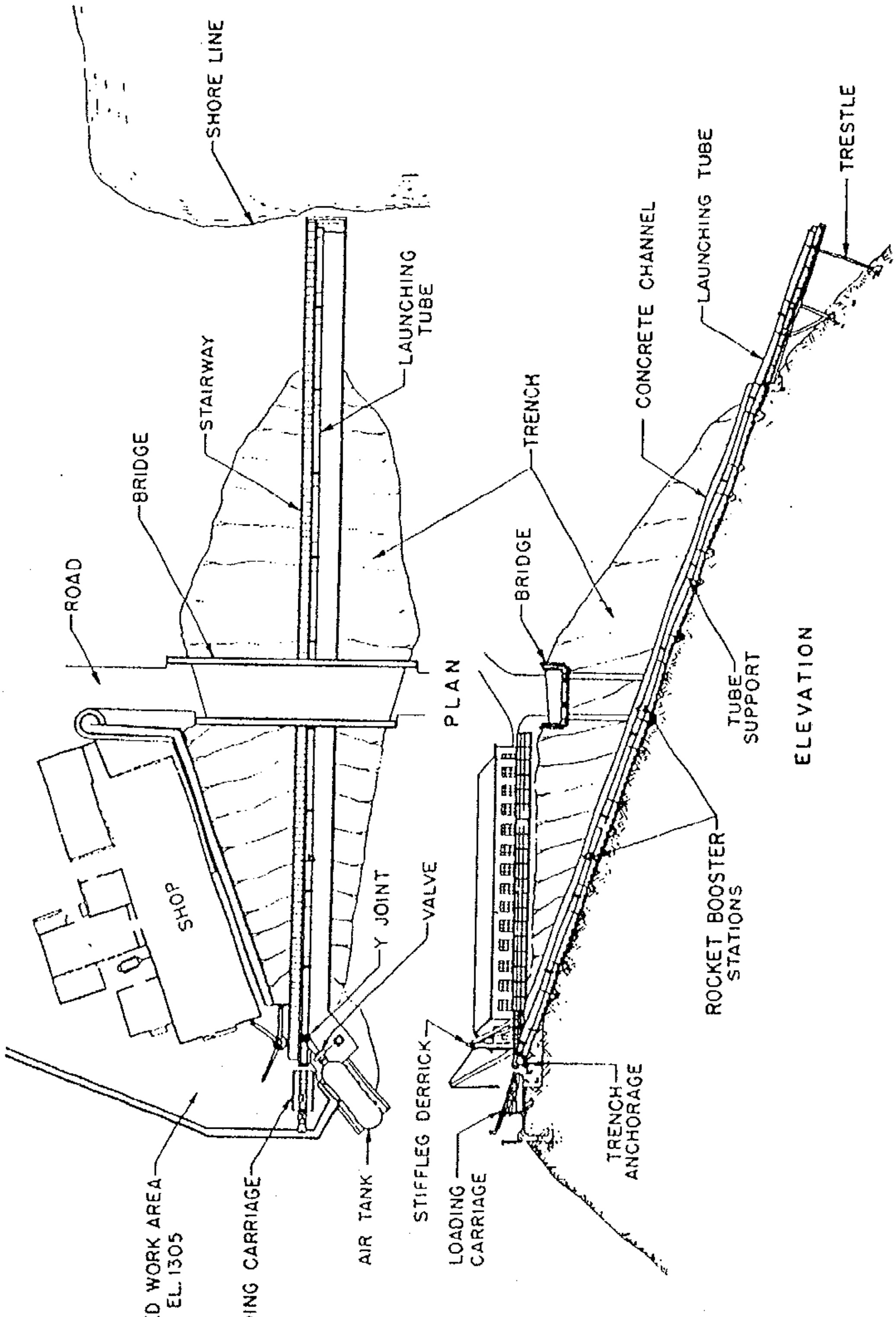


FIGURE 26. Fixed-Angle Launcher Plan and Sectional Elevation.

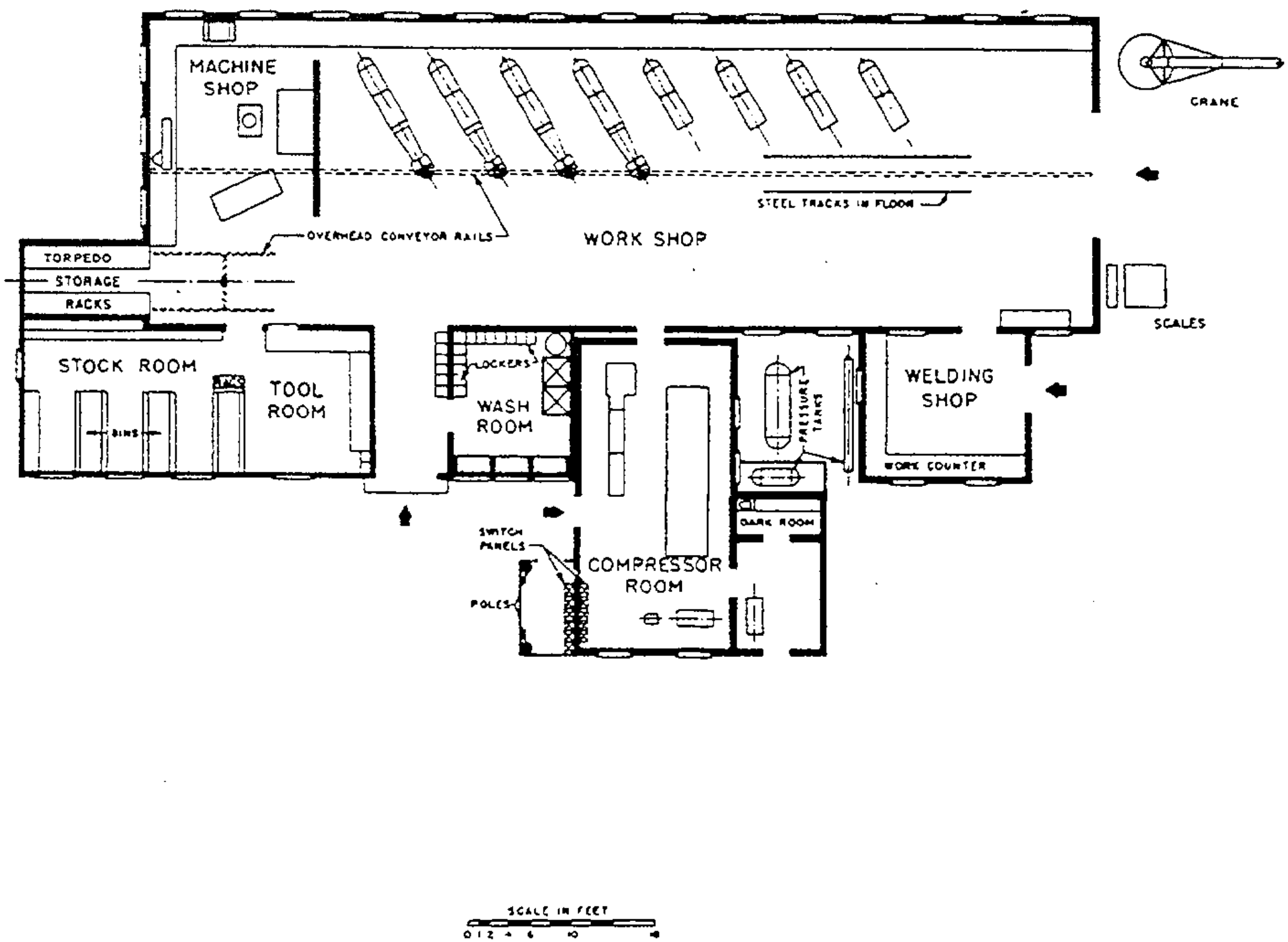


FIGURE 27. Plan of Torpedo Shop Circa 1993.

INDEX TO VARIABLE ANGLE LAUNCHER WRITTEN OPERATING PROCEDURES

TABLE 3-1. VAL CONTROL ROOM LAUNCH PROCEDURES (PAGE 1 of 4)

STEP	PROCEDURE
1.	Obtain the lake level from the Administration Office. Launch angle and projectile velocity are obtained from the test specifications.
2.	Using lake level, launch angle, and projectile velocity data, calculate the following data from the appropriate charts in the VAL Control Room. a. VAL pin position b. Muzzle Station c. Water entry point d. Side View Camera Station (water entry point -26 feet) e. Main Tank launch pressure f. Camera start and stop times.
3.	Enter the data above on the Data Sheet.
4.	Reposition launcher bridge if required. (See Section 3.2)
5.	Select main air system compressor.
6.	Select appropriate Main Tank pressure gauge.
7.	If using the Chicago Pneumatic Compressor (CPC), set up Auxiliary Air Controller. The minimum pressure for the auxiliary tanks is 300 psi.
8.	Check Quick Acting Valve (QAV) oil level. This must be done once a day during scheduled tests: a. pump oil from the main oil tank back into the QAV with the oil pump; b. visually observe oil at the filler plug or sight glass.
9.	Activate the 48 V electrical systems for the Supervisory Panel and VAL Control by switching them to ON.
10.	Turn on the LP air compressor and the 110V electrical circuit for the air horn in the Torpedo Shop.
11.	Turn on IRIG timing generator.

TABLE 3-1. VAL CONTROL ROOM LAUNCH PROCEDURES (PAGE 2 of 4)

STEP	PROCEDURE
12.	Select the appropriate cameras and other telemetry systems on the Supervisory Panel.
13.	Set Supervisory Panel switch for manual or sequential activation.
14.	Confirm the operation of the safety interlock system to prevent actual premature launching. To achieve a GREEN interlock lamp the following systems must be energized: a. breech door of 22.5-inch tube closed and secured, b. breech door of 32-inch tube closed and secured (Interlock not yet connected), c. torpedo release interlock closed, d. launcher bridge evacuation check station switch energized. **CAUTION** THE BRIDGE EVACUATION SWITCH IS CLOSED BY THE LAUNCHING CREW AT THE TIME OF THE EVACUATION. A GREEN LIGHT WILL LIGHT AND AN INTERMITTENT BELL WILL SOUND WHEN THE LAST PERSON ON THE LAUNCHER BRIDGE CLOSES THE EVACUATION SWITCH.
15.	Charge *only* the Auxiliary Air tanks to approximately 300 psi. The transducer read-out (rear rack, upper left panel) should indicate 250 psi.
16.	Install arming plug and position associated switches for manual launch operation.
17.	Operate the Safety Release switch.
18.	Fire the Launch Switch to test the QAV.
19.	Observe the operation of the QAV system by sight and sound to ensure proper operation.
20.	Open the Auxiliary Air bleed valve to release all pressure from the system.
21.	Note that the QAV closes by observing the HAT section of the valve.
22.	Remove the arming plug.

TABLE 3-1. VAL CONTROL ROOM LAUNCH PROCEDURES (PAGE 3 of 4)

STEP	PROCEDURE
23.	Assist in establishing communications between the Recording Station and the various camera stations.
24.	Assist in the internal instrument checkout when the missile has been loaded into the tube.
25.	When all personnel have been evacuated from the launcher bridge, establish Launch Time (T -X minutes), based on the period required to charge the pressure system with the pre-calculated air pressure.
26.	With missile in place and breech secured and prior to charging the air system, light the RED Navigation Warning Lights and sound the launching alarm to clear boats from the reservoir launch area.
27.	Contact the Division of Highways and inform them of the necessity of blocking traffic on Highway 39 if there is a possibility of a projectile broach.
28.	Commence Main Tank pressurization sequence as in Table 3-2.
29.	When Main Tank pressure reaches approximately 30 psi, check Main Tank bleed valve operation.
30.	Commence projectile launch count down.
31.	At time T -30 minutes (a) notify divers (if required), (b) notify dam keeper (if required), (c) notify roadblock personnel.
32.	At time T -20 test radio communications if required.
33.	At time T -15 send vehicle down Highway 39 to clear tourists from view points if required.
34.	At time T -10 sound one long blast on the air horn (First Mark).
35.	At time T -5 set road blocks at Main Gate and at the turnout below the dam structure if necessary.

TABLE 3-1. VAL CONTROL ROOM LAUNCH PROCEDURES (PAGE 4 of 4)

STEP	PROCEDURE
36.	At time T -2 install the arming plug and select the proper firing switches.
37.	At time T -1:30 make the final corrections to Main Air pressure with Main Air bleed valve.
38.	At time T -60 seconds sound four short air horn blasts (Second Mark).
39.	At time T -desired seconds energize camera sequencer start switch if sequence mode has been chosen or energize safety release for manual launch.
40.	At time T -0 activate launch switch for manual launch. End count down.
41.	Note the time of day and enter time on the Data Sheet. Commence post-launch procedure (Table 3-4).

TABLE 3-2. VAL MAIN AND AUXILIARY AIR TANK PRESSURIZATION PROCEDURES (PAGE 1 of 4)

STEP	PROCEDURE
	NOTE There will necessarily be some overlap between the procedures outlined in this table and table 3-1; however, this redundancy should clarify the overall procedures.
1.	Energize the VAL Supervisory and VAL Control panel switches (located behind the Launch Control entrance door) to activate the 48V controller systems, the Chicago Pneumatic Compressor (CPC) stop/start switches, the HP (2200 psi) compressor stop/start switch, and the LP air compressor. **WARNING** THE LP COMPRESSOR CHARGES SAFETY VALVE DIAPHRAGMS IN THE AIR SYSTEM. DIAPHRAGM AIR PRESSURE IS INDICATED ON THE RACK PANEL ABOVE THE AUXILIARY AIR CONTROL PANEL. IF THE LOW PRESSURE INDICATOR IS LIT, DO NOT ATTEMPT TO LAUNCH: THE DIAPHRAGM AIR PRESSURE IS TOO LOW TO OPERATE THE DIAPHRAGM VALVES.
2.	Determine launch pressure from the Launching Curves (which provide pressure/velocity data).
3.	Select the appropriate Main Tank pressure gauge on the Main Air Tank control panel.
4.	Manually set the Main Tank controller to the correct pressure +25 psi or more to allow for system leakage.
5.	Select main air system compressor.

TABLE 3.2. VAL MAIN AND AUXILIARY AIR TANK PRESSURIZATION PROCEDURES (PAGE 2 of 4)

STEP	PROCEDURE
	NOTE There are two main air system compressors, the Chicago Pneumatic Compressor (1000 psi), located in the Compressor Compound, and the HP (2200 psi) compressor located at the lower site. Since use of each of these systems requires a separate procedure, they are treated separately below. The following steps (13 through 19) refer to the CPC (1000 psi) operation. Steps 12A through 19A refer to the HP (2200 psi) compressor operation.
6.	If using the CPC, energize the Compressor Compound circuit breakers.
7.	Set Auxiliary Air Control black-tipped pointer to Main Tank pressure as required.
8.	Set Auxiliary Air controller green-tipped pointer to Main Tank pressure requirement plus 50 psi.
	NOTE The Auxiliary Air controller actually controls the CPC start/stop operations. If for any reason the Auxiliary Air controller must be bypassed, the CPC can be operated by using the compressor start/stop switches.
9.	Confirm the setting of the required pressure on Main Air control pressure gauge.
10.	Energize navigation warning lights.
11.	Place Main Air Bleed valve switch in center position.
12.	Activate Main Tank controller panel. Main Tank inlet lamp should indicate OPEN (RED).
13.	Energize Auxiliary Air controller. The following should occur: a. compressor will start as indicated by RUN light; b. Auxiliary Air controller pressure gauge should start to indicate pressure.
14.	Monitor Main Tank pressure gauge. When Main Tank pressure reaches approximately 30 psi, check Main Tank bleed valve operation.

TABLE 3-2. VAL MAIN AND AUXILIARY AIR TANK PRESSURIZATION PROCEDURES (PAGE 3 of 4)

STEP	PROCEDURE
15.	When Main Tank pressure is attained, ensure that the inlet valve lamp indicates that the inlet valve is closed (GREEN).
16.	Monitor the Auxiliary Air controller gauge, observing that the black pointer indicates a steady increase in air pressure.
17.	When Auxiliary Air controller black pointer reaches the green-tipped pointer, observe the lighting of the compressor STOP light (GREEN), indicating compressor shutdown.
18.	Observe Main Air controller panel safety pressure lamp which should be GREEN.
19.	With system fully charged and observing all safety precautions, commence projectile launch count down (Table 3-1, Steps 29-40).
	NOTE
	If using the HP (2200 psi) compressor, observe the following procedures, designated 13A through 20A.
13A.	Manually open the HP Air Valve located to the right of Pre-Launch Panel.
14A.	Monitor Main Tank charging pressure on the HP pressure gauge adjacent to the HP Air Valve control.
15A.	When Main Tank pressure reaches approximately 30 psi, check Main Tank bleed valve operation.
16A.	When pre-calculated Main Tank pressure is attained, close Main Tank inlet valve by depressing the inlet valve switch.
17A.	Ensure that the Main Tank inlet valve lamp is GREEN, indicating that the inlet valve is closed.
18A.	Continue charging Auxiliary Tanks, observing Auxiliary Air controller pressure gauge.
19A.	When the Auxiliary Air controller gauge black pointer reaches the Auxiliary Air controller green pointer, manually close the HP Air Valve.

TABLE 3-2. VAL MAIN AND AUXILIARY AIR TANK
PRESSURIZATION PROCEDURES (PAGE 4 of 4)

STEP	PROCEDURE
	CAUTION THERE IS NO AUTOMATIC SHUT OFF FOR THE HP COMPRESSOR. OPERATOR MUST OBSERVE AUXILIARY AIR CONTROL PRESSURE TO CLOSE HP VALVE.
20A.	With system fully charged and observing all safety precautions, commence projectile launch count down (Table 3-1, Steps 29-40).

TABLE 3-3. VAL SUPERVISORY PANEL LAUNCH PROCEDURES (PAGE 1 of 2)

STEP	PROCEDURE
1.	Activate the Supervisory Control Panel in Launch Control by energizing the 48V system.
2.	Turn on main power switch (located at extreme left of the Supervisory Panel.),
3.	Select appropriate remote stations for recording of data.
4.	Select SEQUENCE or MANUAL operation for setting of recording instrument operation mode.
5.	Choose remote stations and operational mode by placing switches in proper positions: a. for SEQUENCE mode, instrument switches are placed in UP position; b. for MANUAL mode, instrument switches are placed in DOWN position; c. switches for remote station instruments not selected remain in the OFF (CENTER) position. NOTE Selection of MANUAL or SEQUENCE mode will be indicated by the lights which are lighted in the two double rows of indicator lamps on the Supervisory console. Steps 6 and 7 below refer to MANUAL operation; 6A and 7A to SEQUENCE operation.
6.	With console switches in the MANUAL (DOWN) position, signal MANUAL operation of instruments to the remote stations.
7.	Remote stations signal READY to Control Room and Recording Station by placing local switches in READY position. RED light in the upper double row of RED/GREEN lights will change to GREEN, indicating that the remote station is ready for a launch and is in the MANUAL mode of operation.
6A.	With Supervisory console switches in the SEQUENCE (UP) position, signal SEQUENCE mode to the Recording Station.

TABLE 3-3. VAL SUPERVISORY PANEL LAUNCH PROCEDURES (PAGE 2 of 2)

STEP	PROCEDURE
7A.	Remote stations signal READY to Control Room and Recording Station by placing local switches in READY position. RED light in lower double row of RED/GREEN lights will change to GREEN, indicating that the remote station is ready for a launch in SEQUENCE mode.
8.	If Control Room or remote station observes malfunction, depress RECALL switch to abort launch. RED light lights as appropriate.
9.	When Recording Station has set sequencing timers, energize SEOUENCE switches in Recording Station to light, indicating that the sequencer is READY. When sequence timers are ready, Recording Station signals READY, changing RED lights in lower double row to GREEN.
10.	When all appropriate lights at the Recording Station and Control Room show GREEN (READY) status, commence final launch procedure.

TABLE 3-4. VAL POST LAUNCH PROCEDURE (PAGE 1 of 1)

STEP	PROCEDURE
1.	At completion of launch, open Main Tank air inlet valve to bleed all air from the main air system.
2.	Man the Control Room scope and position cross-hair in the center of the projectile bubble track if required and record setting.
3.	Secure Launch Control Room by deactivating the 48V electrical system for the Supervisory Panel, VAL Control panel.
4.	Secure LP air compressor and 110V system for the air horn in the Torpedo Shop.
5.	Secure IRIG timing generator.
6.	Collect data from film records of missile performance and transfer to data sheets.
7.	Enter appropriate data on missile physical properties on data sheet.

TABLE 3-5. VAL MAIN HOIST AND WINDSTAY OPERATING PROCEDURES (PAGE 1 of 4)

STEP	PROCEDURE
	NOTE There is a portable remote control panel for the main hoist which can be used on the bridge launcher carriage. The portable panel plugs into receptacles on the launcher slope.
1.	Obtain correct carriage locking pin hole number from Launch Control.
2.	Inspect the launcher bridge support carriage and launcher track rails to ensure that the area is clear of obstructions and that all electric cables and air system lines are clear of the tracks. Clean and lubricate carriage pin holes with a greased swab.
3.	If the launcher is to be moved some distance, disconnect air hoses and electric cables.
4.	Set Main Hoist RAISE/LOWER control to the middle or OFF position. (Work control to remove any possible corrosion on the rheostat.)
5.	Set windstay control switches to the Number 1 position; place brake switches in the SET position.
6.	Establish communications between the Launcher carriage (Ext. 56) and the Hoist Control (Ext. 42).
7.	Energize the following circuits on the Hoist Control console. Observe the order below: a. energize DC exciter, lighting RED light; b. activate east and west windstay winches, lighting RED motor indicator lights; AMBER brake indicator lamps on console light; c. energize Main Hoist motor, lighting RED motor indicator lamp, RED emergency brake and service lamps and BLUE interlock indicator lamp on console.
8.	Energize the carriage hydraulic system at the 440V load-center located on the bridge carriage platform.

TABLE 3-5. VAL MAIN HOIST AND WINDSTAY OPERATING PROCEDURES (PAGE 2 of 4)

STEP	PROCEDURE
9.	Remove the hydraulically operated locking pins. Upper pins are removed first. NOTE If necessary, the Main Hoist operator will remove the carriage weight from the pins by placing the Main Hoist control to the TENSION setting and applying tension to the main drive cable as needed. If this is insufficient, a gentle rocking of the carriage, using the control RAISE/LOWER rheostat, may be necessary to free the pins.
10.	When the locking pins have been removed and safe operation is indicated, Carriage Crew announce ALL CLEAR.
11.	Release both east and west windstay brakes by throwing brake switches to the OFF position. AMBER windstay brake lights should be OFF.
12.	Place the Main Hoist control rheostat in the SPEED position or the TENSION position as appropriate. The SPEED position allows a faster launcher motion.
13.	Commence repositioning of the launcher bridge, observing all safety precautions. CAUTION BEFORE AND DURING THE LAUNCHER MOVE, KEEP A CONSTANT VISUAL AND TELEPHONE CONTACT WITH THE CARRIAGE CREW. OBSERVE THE SURROUNDING AREA. WATCH THE POSITION OF THE LAUNCHER BARGES IN RESPECT TO RANGE LINES AND WINDSTAY CABLE SLACK. LISTEN FOR ANY STRANGE SOUNDS. BE PREPARED TO STOP THE LAUNCHER IMMEDIATELY.

TABLE 3-5. VAL MAIN HOIST AND WINDSTAY OPERATING PROCEDURES (PAGE 3 of 4)

STEP	PROCEDURE
14.	To reposition launcher, rotate the Main Hoist control rheostat slowly in the RAISE or LOWER direction as required. Ensure that both the service and emergency brake lights are OFF. **CAUTION** DO NOT ALLOW MAIN DRIVE AMMETER TO EXCEED 100 AMPS. NOTE Because the launcher structure weighs more than the counterweight car, little power is required to lower the launcher. However, to raise the launcher it is sometimes helpful to increase windstay winch torque to the Number 2 or Number 3 position.
15.	If the launcher bridge drifts too close to the Range line, take up on the windstay winch on the side opposite the direction of the drift. Keep the windstay cables taut.
16.	When launcher bridge reaches the correct locking pin number, a. stop Main Hoist Drive; b. set windstay winches to control position Number 1; c. set windstay brakes to SET.
17.	Replace the carriage locking pins. (See Step 9 and Note.)
18.	When launcher is secure, secure Main Hoist power.
19.	Release windstay winch brakes.
20.	Align launcher on the firing range by following the procedure below. a. set launcher bridge viewing scope on the black and white target at the far end of the launcher structure; b. center the target in the viewing scope by adjusting barge position with the windstay winches.

TABLE 3-5. VAL MAIN HOIST AND WINDSTAY OPERATING PROCEDURES (PAGE 4 of 4)

STEP	PROCEDURE
21.	When launcher is properly aligned, place windstay brakes in SET position. Set east and west windstay winches to control position Number 1.
22.	Secure DC exciter switch, windstay winch motors, and carriage pin removal system.
23.	Secure building.

TABLE 3-6. VAL LAUNCHER TUBE LOADING PROCEDURES (PAGE 1 of 4)
(22.5-INCH TUBE FOR NORMAL, HARD-RING PROJECTILE)

STEP	PROCEDURE
	CAUTION ENSURE THAT THERE IS NO AIR PRESSURE IN THE MAIN TANK OR THE MAIN AIR SYSTEM BEFORE PROCEEDING WITH TUBE LOADING:
1.	If muzzle scoops are used, set scoops as required: a. increase projectile pitch by opening the upper scoop, b. decrease projectile pitch by opening the lower scoop, c. if no change in pitch is required, open both scoops fully and equally.
2.	With missile on projectile dolly, weigh missile at weigh station to provide the test conductor with gross weight for calculating launch pressure/velocity.
3.	Move projectile dolly and projectile on to projectile loading platform.
4.	Position projectile car level with the loading platform.
5.	Load dolly and projectile on the projectile car.
6.	Position projectile car level with the launcher bridge loading platform.
7.	Attach bridge crane cable to the projectile.
8.	Energize hydraulic projectile ram system.
9.	Move projectile ram full aft.
10.	Raise projectile from the dolly on the loading platform and lower it to the projectile loading tray.
11.	Connect projectile (if a hard ring projectile) to the projectile retainer shackle on the hydraulic ram shaft.
12.	Energize the launcher tube breech door controls and manually remove the breech door pin. Raise the launcher tube door.
13.	Secure breech door with breech door safety cable.

TABLE 3-6. VAL LAUNCHER TUBE LOADING PROCEDURES (PAGE 2 of 4)
(22.5-INCH TUBE FOR NORMAL, HARD-RING PROJECTILE)

STEP	PROCEDURE
14.	Remove and inspect rubber breech door seal.
15.	Move projectile loading tray forward to engage the launcher tube and insert breech door pin to secure the tray to the launcher tube. NOTE A light breech door pin which is not long enough to engage the breech door interlock switch is used to secure the loading tray to the launcher tube breech.
16.	Tape projectile instrumentation leads to the top of the projectile.
17.	Raise projectile loading tray to match the launcher tube angle.
18.	Back off the safety interlocked tension link assembly to extract the projecting retainer lugs from the interior of the launcher tube.
19.	Lower projectile into the launcher tube with the hydraulic ram.
20.	Secure projectile unit in tube with cable or block.
21.	Disconnect ram retainer and move ram shaft aft to attach ram shaft extension.
22.	Attach extension to ram shaft and to projectile.
23.	Release securing cable or block.
24.	Lower projectile into tube until retainer lugs of tension link assembly are visible.
25.	Place tension link assembly shear link in position and turn the retaining screw until the shear link is secured tightly. Screw in safety lock.

TABLE 3-6. VAL LAUNCHER TUBE LOADING PROCEDURES (PAGE 3 of 4)
(22.5-INCH TUBE FOR NORMAL, HARD-RING PROJECTILE)

STEP	PROCEDURE
	NOTE When the tension link assembly shear link is secured in place, the retainer lugs' will project into the launcher tube.
26.	Lower projectile until it locks against the tension link assembly retainer lugs.
27.	CAUTION WATCH RAM RETAINER SHAFT LINKAGE TO ENSURE THAT THE PROJECTILE WEIGHT IS TRANSFERRED TO THE TENSION LINK ASSEMBLY RETAINER LUGS.
27.	Release projectile and withdraw projectile ram.
28.	Remove hydraulic ram shaft extension.
29.	Lower projectile cradle to level position.
30.	Make instrumentation hook-ups through the launcher tube hand hole.
31.	Replace rubber breech seal. NOTE The flat side of the rubber breech seal should face the installer.
32.	If pyrotechnics are required, load pyrotechnics through hand hole. CAUTION IF CAPS ARE USED, THE BREECH DOOR SHOULD BE CLOSED. IF ROCKET PYROTECHNICS ARE USED, BREECH DOOR SHOULD BE OPEN AND THE LOADING PLATFORM CLEARED OF PERSONNEL.

TABLE 3-6. VAL LAUNCHER TUBE LOADING PROCEDURES (PAGE 4 of 4)
(22.5-INCH TUBE FOR NORMAL, HARD-RING PROJECTILE)

STEP	PROCEDURE
33.	Remove light breech door pin.
34.	Retract projectile loading tray.
35.	With all instruments connected and pyrotechnics (if any) installed, disconnect safety cable and lower breech door.
36.	Install breech door pin.
37.	Check instrument read outs.
38.	Secure hand hole. NOTE If pyrotechnics are used, indicate READY to Launch Control Room by operating the appropriate switch on the board located behind the projectile ram.
39.	Call Launch Control to inform of readiness to give green lights and remove safety lock.
40.	Signal READY on projectile loading platform board.
41.	When all personnel have evacuated the launcher bridge and loading platform, last man push bridge evacuation interlock button.
42.	Secure from tube loading operation. NOTE The procedures for loading a hard-ring projectile in the 32-inch tube are as above. The 32-inch tube has two major differences from the 22.5-inch tube: a. breech door pins are removed and replaced electrically, b. the projectile loading tray extender is electrically powered.

TABLE 3-7. VAL LOADING OF PROJECTILES WITHOUT HARD RING OR WITH SABOT (PAGE 1 of 2)

STEP	PROCEDURE
	CAUTION ENSURE THAT THERE IS NO AIR PRESSURE IN THE MAIN TANK OR THE MAIN AIR SYSTEM BEFORE PROCEEDING WITH LOADING OPERATIONS.
1.	Follow steps 1 through 9 in Table 3-6.
2.	Measure 1/2-inch nylon line to the length required to position and retain projectile with one half of the projectile body in the launcher tube. **NOTE** The line should be doubled; projectile ram should be full aft.
3.	Reeve both ends of the prepared line through the ram shaft shackle and through the pad-eye located on the projectile. Attach the line to the end of the launching tube, forming a complete loop of double line.
4.	Energize launcher tube breech door controls and raise breech door.
5.	Secure breech door with breech door safety cable.
6.	Remove and inspect rubber breech door seal.
7.	Move projectile loading tray forward and insert breech door pin to secure the loading tray to the launcher tube.
8.	Tape projectile instrumentation leads to the top of the projectile.
9.	Back off the safety interlocked tension link assembly to extract the retainer lugs from the interior of the launcher tube.
10.	Raise projectile loading tray to match the launcher tube angle, sliding the projectile into the tube until slack in line is gone.
11.	Make necessary instrument checks and test projectile.

TABLE 3-7. VAL LOADING OF PROJECTILES WITHOUT HARD RING OR WITH SABOT (PAGE 2 of 2)

STEP	PROCEDURE
12.	Insert 1/2-inch hold-back line through pad-eye on projectile.
13.	Using the ram/shackle reeving, lower the projectile with the hydraulic ram until it passes the launcher tube hand-hole.
14.	Open lower hand hole and secure hold-back line to the pad-eye on the inside of the lower hand-hole cover.
15.	Secure lower hand-hole.
16.	Remove retaining/positioning line.
17.	Complete steps 29 through 42 of Table 3-6.

TABLE 3-8. VAL RECORDING STATION LAUNCH PROCEDURES (PAGE 1 of 3)

STEP	PROCEDURE
1.	Energize the following switches located behind the instrument racks: a. Intercom and Sequencer Pulse Generator, b. hydrophone amplifiers (if required), c. auxiliary timer, d. Power Supply, 6VDC e. sequencer distribution system f. auxiliary timer relay circuits, g. position interferometer (PI), h. electronic timer relay circuits, i. break stick circuit.
2.	Energize the following switches located in front of the racks: a. Power Supply, 24 VDC, b. Oscillograph
3.	Ensure that all three panel meters indicate the correct DC voltage (6V, 24V, 48V). NOTE The 48 VDC supply is never turned off.
4.	Obtain the following information from Launch Control: a. launcher angle, b. projectile velocity, c. run or launch number, d. camera stations to be used, e. special instrumentation requiring START/STOP signals.

TABLE 3-8. VAL RECORDING STATION LAUNCH PROCEDURES (PAGE 2 of 3)

STEP	PROCEDURE
5.	Using existing charts, determine camera START/STOP times based on launcher angle/velocity data which allows charts to be used to determine time unit is in tube and time of air flight to water entry. (See Section 3.4.4 for calculations.)
6.	Set up sequence timers with the information determined in Step 5.
7.	Check out camera stations by observing the following: a. energize appropriate automatic sequence timer (GREEN light); b. start sequencer time pulse generator with sequencer test switch; c. turn timer to OFF (RED light) when test is completed. NOTE The cameras cannot be tested unless the arming plug is installed because the sequencer test lock-out circuit is only energized with the arming plug in. The lock-out circuit prevents the operation of the sequencer by the Recording Station independent of Launch Control.
8.	Check the break stick circuit by energizing proper circuit (22.5-inch or 32-inch launcher tube), and observe that the indicator lamp lights and the galvanometer deflects.
9.	Ensure that the oscillograph is operable by observing the following: a. IRIG time signal present, b. paper supply is adequate, c. run off leader, d. set speed button to 64 inches/second.
10.	Observe all selected instrument stations show GREEN or READY on the instrument station repeater lamps panel.

TABLE 3-8. VAL RECORDING STATION LAUNCH PROCEDURES (PAGE 3 of 3)

STEP	PROCEDURE
11.	Prior to one minute warning or at test conductor's request, energize all automatic sequencing timers to be used in the test: Stand by for launch.
12.	At time T -3 seconds, observe commencement of sequencer pulse generator and monitor RUN TIME INDICATOR lamps for any malfunction.
13.	Listen to hydrophone speaker (if used) and attempt to count the number of caps that have detonated.
14.	At the completion of launch, perform the following actions: a. remove recording take-up magazine; b. secure the switches described in Steps 1 and 2; c. fill out data sheets which include: 1) oscillograph channel assignments, 2) Recording Station Launching Data Sheet, 3) Sequencer Time Setting Sheet.
15.	Secure from launch; secure space.

TABLE 4-1. VAL MAIN DRIVE HOIST, WINDSTAY, PROJECTILE CAR, AND PERSONNEL CAR LUBRICATION

EQUIPMENT	APPLICATION	FREQUENCY	RECOMMENDED
VAL MAIN DRIVE WINCH			
Exposed Bull Gear	Swab	As Required	Union Gearite *
Electric Motor	Grease Fittings	6 Months	Union Unoba F-1 *
Falk Coupling	Hand Pack	Yearly	Unoba F-1 *
Falk Gear Box	Reservoir		Union Turbine Oil 1000 *
Drive Shaft Bearings	Grease Fittings	Monthly	Union Unoba F-1 *
Drum Shaft Bearings	Grease Fittings	Monthly	Union Unoba F-1 *
Cable Guide Shaft-Bearings	Grease Fittings	Monthly	Union Unoba F-1 *
Cables	Swab	As Required	Union Cable Lubrication *
WINDSTAY (2)			
Electric Motors	Spring Oil Cups	3 Months	Union Turbine Oil 315 *
Falk Gear Box	Reservoir	Maintain/Level Change every 6 Months	Union Turbine Oil 1000 *
Falk Coupling	Packing	Repack-Yearly	Union Unoba F-1 *
Cable Blocks	Grease Fittings	Monthly	Union Unoba F-1 *
Drum Shaft Bearings	Grease Fittings	Monthly	Union Unoba F-1 *
Locking Shaft	Grease Fitting	Monthly	Union Unoba F-1 *
Cable		As Required	Union Cable Lubricant *
VAL PROJECTILE CAR			
Miscellaneous Bearings	Grease Fittings	Monthly	Union Unoba F-1 *
Chain	Hand Apply	As Required	Union Line Marok 315 *
Exposed Gears	Swab	As Required	Union Unoba F-1 *
PERSONNEL CAR WINCH			
Electric Motor	Greased Fittings	6 Months	Union Unoba F-1 *
Reduction Gear Case	Reservoir	Maintain Level Change Every 6 Months	Union Worm Gear 90 *
Drum Shaft Bearing	Grease Fitting	Monthly	Union Unoba F-1 *
Cable	Swab	As Required	Union Cable Lubrication *
PROJECTILE CAR WINCH			
Electric Motor	Grease Fittings	6 Months	Union Unoba F-1 *
Reduction Gear Case	Reservoir	Maintain Level Change Every 6 Months	Union Worm Gear 90 *
Drum Shaft Bearing	Grease Fitting	Monthly	Union Unoba F-1 *
Cable	Swab	As Required	Union Cable Lubrication *

*or equivalent

TABLE 4-2. LUBRICATION OF VAL LAUNCHER BRIDGE, SUPPORT CARRIAGE AND LOADING PLATFORM MACHINERY (PAGE 1 OF 2)

EQUIPMENT	APPLICATION	FREQUENCY	RECOMMENDED
LOWER END OF VAL			
Hinges (2)	Pack Grease Around Pins	As Required	Union Unoba F-1 *
VAL SUPPORT CARRIAGE			
Timken Wheel Bearings	Reservoir		Union MP Gear-Lubricant 80/90 *
Lock Pin Hydraulic System (Slow Pressure, Ingersol-Rand Compressor)	Reservoir	Maintain Level Change 6 Months	Union Turbine Oil 150 *
PROJECTILE LOADING PLATFORM			
Electric Motor	Grease Fittings	6 Months	Union Unoba F-1 *
Compressor (Type 30)	Crankcase	Maintain Level/ Change 6 Months	Union Turbine Oil 150 *
Hydraulic System Ram For Loading Projectiles	Reservoirs (2)	Maintain Level/ Change 6 Months	Union Turbine Oil 150 *
Tube Breech Door Opening Electric Motors	Sealed		
Breech Door Opening Gear Boxes	Reservoirs	Maintain/Level Change 6 Months	Union Worm Gear 90 *
Breech Door Hinges	Grease Fittings	Monthly	Union Unoba F-1 *
Torpedo Launcher Pillow Blocks (2)	Grease Fittings	Monthly	Union Unoba F-2 *
Quick Acting Valve O-Rings	Grease Fittings	Each Launch	Union Unoba F-1 *
Quick Acting Valve Oil System	Reservoir	Keep Full	Union Turbine Oil 1000 *
PROJECTILE LAUNCHING HOIST (32" TUBE)			
Electric Motors	Grease Fittings	3 Months	Union Unoba F-1 *
Gear Case	Reservoir	6 Months	Union Worm Gear 90 *
Pulley Wheels	Grease Fittings	3 Months	Union Unoba F-1 *
Cables	Swab	As Required	Union Cable Lubricant *
Shand & Jurs Cable Drum	Reservoir	Keep Full	Union Worm Gear 90 *
VAL PROJECTILE WINCH			
Electric Motors	Spring Oil Cups	3 Months	Union Turbine Oil 315 *
Falk Gear Box	Reservoir	Maintain/Level Change 6 Months	Union Turbine Oil 1000 *
Falk Coupling	Packing	Repack Yearly	Union Unoba F-1 *

*or equivalent

TABLE 4-2. LUBRICATION OF VAL LAUNCHER BRIDGE, SUPPORT CARRIAGE AND LOADING PLATFORM MACHINERY (PAGE 2 OF 2)

EQUIPMENT	APPLICATION	FREQUENCY	RECOMMENDED
VAL PROJECTILE WINCH (CONT.)			
Cable Blocks	Grease Fittings	Monthly	Union Unoba F-1 *
Drum Shaft Bearings	Grease Fittings	Monthly	Union Unoba F-1 *
Locking Shaft	Grease Fitting	Monthly	Union Unoba F-1 †
Cable	Swab Full Length	As Required	Union Cable Lubricant *
MISCELLANEOUS			
Torpedo Shop Winch Gear Box	Reservoir	Maintain/Level Change 6 Months	Union Worm Gear 90 *
Miscellaneous Grease Points	Grease Fittings	6 Months	Union Unoba F-1 *
RANGE LINE WRENCH (2)			
Shaft Bearings	Grease Fittings	Monthly	Union Unoba F-1 *
Cable	Swab Full Length	As Required	Union Cable Lubricant *

*or equivalent

TABLE 4-3. QUICK ACTING VALVE LUBRICATION PROCEDURES
(BUFFER OIL CHECK AND PISTON LUBRICATION)

STEP	PROCEDURE
	NOTE
	This table is divided into three sections. Since all operations occur at the same station, they can be performed during the same interval.
	QAV BUFFER OIL CHECK (BEFORE EACH LAUNCH)
1.	Pump oil from the main oil tank back into the QAV with the oil pump.
2.	Observe oil at the sight glass or at the filler plug.
	QAV AUXILIARY PISTON LUBRICATION
1.	Connect grease pump line to center fitting.
2.	Open grease valve for center fitting.
3.	Operate pump one up stroke, one down stroke.
4.	Close grease valve for center fitting.
	QAV MAIN PISTON LUBRICATION
1.	Connect grease pump line to grease fitting marked UPPER.
2.	Open associated grease valve.
3.	Operate pump one up stroke, one down stroke.
4.	Close grease valve.
5.	Connect grease pump line to grease fitting marked LOWER.
6.	Open associated grease valve.
7.	Operate pump two up strokes, two down strokes.
8.	Secure grease valve.

TABLE 4-4. STORING VARIABLE-ANGLE LAUNCHER ON TEMPORARY SUPPORT (PAGE 1 of 2)

STEP	PROCEDURE
1.	Load support columns. and lateral bracing struts on the barge and assembled at dockside as shown in BUORD Sketch 220613.
2.	Lay struts on top of columns.
3.	Lash blocks at panel points 2 and 3 and fasten two winches in place on barge and two winches on the compressor support platform of the launcher bridge carriage. Prevent lashings from chafing by using hardwood blocks.
4.	Remove range line on port side of range.
5.	Move barge into position and moor.
6.	Prepare launcher bridge for storage by performing the following actions: a. disconnect all instrumentation and power circuits from rear view camera station. b. disconnect range centerline cable; c. disconnect high pressure air line flexible hose; d. disconnect water line flexible hose; e. disconnect public address system speaker.
7.	With barge in position, reeve cables through blocks and attach slings to support structure struts and support columns.
8.	Take up on both pairs of winches (barge winches and compressor platform winches) until the support struts are clear of the barge and the column assembly is at approximately 45°.
9.	Move bridge carriage and bridge up the launcher slope until the column assembly is nearly vertical and remove pins at lower ends of column assembly.
10.	Continue moving the launcher bridge up the slope until the ends of the column assembly are located vertically above pin 56 holes.
11.	Lower column assembly and align with main launcher carriage pin holes on main rails and insert pins at pin 56.

TABLE 4-4. STORING VARIABLE-ANGLE LAUNCHER ON TEMPORARY SUPPORT (PAGE 2 of 2)

STEP	PROCEDURE
	CAUTION POSITIONING OF LAUNCHER BRIDGE MUST BE COORDINATED WITH TAKE UP AND BRAKING WINCHES HOLDING THE SUPPORT COLUMN ASSEMBLY.
12.	Move launcher bridge carriage down the slope until the support column assembly is in approximate use position.
13.	Lower lateral bracing struts and pin to main rails.
14.	Align pin holes at the tops of the support struts with the corresponding holes in the support columns and insert pins.
15.	Disconnect support structure rigging tackle from columns and struts; unlash rigging and lower with ropes.
16.	Lower lake level until the launcher bridge structure is just resting on temporary support.
17.	Secure launcher pontoon barge structure to outboard anchors.
18.	Rig lower ends of launcher bridge to transfer windstay sheaves from pontoon barge structure to launcher bridge.
19.	Continue to lower lake until pontoon barges and connecting bridge are free from the launcher bridge.
20.	Install tie down clamp between the launcher bridge and the temporary support. (Ref. BUORD Sketch 220080)
21.	Float pontoon barge structure to anchorage.
22.	Disconnect power to windstay winches, main hoist, and launcher carriage pin removal hydraulic system.